QSCAT-R: The QuikSCAT Tropical Cyclone Radial Structure Dataset

Daniel R. Chavas
Jonathan L. Vigh

NCAR Technical Notes
NCAR/TN-513+STR

National Center for
Atmospheric Research
P. O. Box 3000
Boulder, Colorado
80307-3000
www.ucar.edu

NCAR | UCAR
National Center for Atmospheric Research

National Science Foundation
NCAR IS SPONSORED BY THE NSF

NCAR TECHNICAL NOTES

http://library.ucar.edu/research/publish-technote

The Technical Notes series provides an outlet for a variety of NCAR Manuscripts that contribute in specialized ways to the body of scientific knowledge but that are not yet at a point of a formal journal, monograph or book publication. Reports in this series are issued by the NCAR scientific divisions, serviced by OpenSky and operated through the NCAR Library. Designation symbols for the series include:

EDD – Engineering, Design, or Development Reports
Equipment descriptions, test results, instrumentation, and operating and maintenance manuals.

IA – Instructional Aids
Instruction manuals, bibliographies, film supplements, and other research or instructional aids.

PPR – Program Progress Reports
Field program reports, interim and working reports, survey reports, and plans for experiments.

PROC – Proceedings
Documentation or symposia, colloquia, conferences, workshops, and lectures. (Distribution maybe limited to attendees).

STR – Scientific and Technical Reports
Data compilations, theoretical and numerical investigations, and experimental results.

The National Center for Atmospheric Research (NCAR) is operated by the nonprofit University Corporation for Atmospheric Research (UCAR) under the sponsorship of the National Science Foundation. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

National Center for Atmospheric Research
P. O. Box 3000
Boulder, Colorado 80307-3000

NCAR/TN-513+STR
NCAR Technical Note

2014-12

QSCAT-R: The QuikSCAT Tropical Cyclone Radial Structure Dataset

Wind radii and radial profiles of wind and rain for Tropical Cyclones globally, 1999-2009

Daniel R. Chavas
Department of Civil and Environmental Engineering,
Princeton University, Princeton, New Jersey

Jonathan L. Vigh
Research Applications Laboratory/Joint Numerical Testbed Program,
National Center for Atmospheric Research, Boulder, Colorado

Joint Numerical Testbed Program
NCAR Research Applications Laboratory

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
P. O. Box 3000
BOULDER, COLORADO 80307-3000
ISSN Print Edition 2153-2397
ISSN Electronic Edition 2153-2400

QSCAT-R: The QuikSCAT Tropical Cyclone Radial Structure Dataset

Wind radii and radial profiles of wind and rain for Tropical Cyclones globally, 1999-2009

Version: 1.000
Release Date: 1 Sep 2014
Dataset creator: Daniel Chavas, Ph.D.

Authors: Daniel R. Chavas, Jonathan L. Vigh

Documentation date: 10 Nov 2014

Table of Contents

Introduction

The QuikSCAT Tropical Cyclone Radial Structure Dataset (QSCAT-R) consists of tropical cyclone (TC) data that have been collected and processed from the following sources:

1) NASA JPL QuikSCAT Tropical Cyclone database, and
2) IBTrACS Best Track (BT) Dataset.

The current version of the dataset includes tropical cyclones from all global ocean basins for the years 1999-2009, during which the QuikSCAT satellite was operational.

The dataset contains QuikSCAT-derived data for the radial structure of tropical cyclones, including:

- radial profiles of total wind speed and its azimuthal and radial components,
- canonical wind radii (64 kt, 50 kt, 34 kt; 12 ms^{-1} (23.3 kt) also included) estimated from the radial profiles of the azimuthal wind and total wind,
- radial profiles of a quantity proportional to rain rate, and
- radial profiles of collocated SSM/I cloud liquid data, when available.

Scope and Purpose of this Document

This documentation serves two primary purposes: a) to describe the structure and indexing of the dataset parameters and its constituent files, and b) to detail the methodology by which each parameter in the dataset was calculated.

Important References

The NASA Jet Propulsion Laboratory (JPL) provides the raw dataset from which QSCAT-R is derived. JPL has created a user-friendly portal for viewing their raw two-dimensional, storm-centered QuikSCAT-estimated near-surface wind vector data: http://tropicalcyclone.jpl.nasa.gov.

For detailed information on the data sources and processing of the raw QuikSCAT data, including the methodology for estimating near-surface wind vectors from QuikSCAT scatterometric measurements and its associated uncertainties:

Stiles, Bryan W., et al. "Optimized Tropical Cyclone Winds From QuikSCAT: A Neural Network Approach." (2013): 1-17.

Fore, Alexander G., et al. "Point-Wise Wind Retrieval and Ambiguity Removal Improvements for the QuikSCAT Climatological Data Set." *International Ocean Vector Wind Science Team Meeting, Annapolis, MD, May*. 2011.

Hoffman, Ross N., and S. Mark Leidner. "An Introduction to the Near–Real–Time QuikSCAT Data." *Weather & Forecasting* 20.4 (2005).

Additionally, for information regarding the methodology for QuikSCAT-based radiometric estimates of precipitation rate:

Ahmad, Khalil A., et al. "Oceanic rain rate estimates from the QuikSCAT Radiometer: A Global Precipitation Mission pathfinder." *Journal of Geophysical Research: Atmospheres (1984–2012)* 110.D11 (2005).

Finally, for information regarding IBTrACS:

Knapp, Kenneth R., et al. "The international best track archive for climate stewardship (IBTrACS) unifying tropical cyclone data." *Bulletin of the American Meteorological Society* 91.3 (2010): 363-376.

Description of the Raw Data Sources

NASA JPL QuikSCAT Tropical Cyclone Database

The QuikSCAT tropical cyclone ocean near-surface (z = 10 m) wind vector database (http://tropicalcyclone.jpl.nasa.gov/) is an optimized version of Version 3 of the complete global QuikSCAT dataset. The dataset is optimized specifically for tropical cyclones and subsets the global data into storm-centered files for all times at which the QuikSCAT swath passed sufficiently close to the storm center. The optimization employs a neural network algorithm to increase accuracy and remove rain contamination in wind speed estimates.

The QuikSCAT dataset has a grid spacing of 12.5 km within an 1800 km wide swath whose location follows the orbit of the satellite around the Earth (see below). The active measurement period spanned 19 July 1999 to 21 November 2009. Measurements are accurate in all weather conditions for winds up to 40 ms^{-1}. The precision of the wind speed estimates in the optimized QuikSCAT tropical cyclone dataset is similar to those of global QuikSCAT Version 3 for speeds below 20 ms^{-1}, but precision is much improved for wind speeds in the range 20-40 ms^{-1}. The tropical cyclone dataset carries a 1-2 ms^{-1} positive bias and a 3 ms^{-1} mean absolute error for all wind speeds up to 40 ms^{-1}. Wind directions are unchanged from the Version 3 wind vector product, which has a direction RMS error of 17.36° (Fore et al. 2014).

Data coverage includes water surfaces only; valid measurements cannot be made over land.

For complete details on the optimized QuikSCAT tropical cyclone database and its underlying methodology, the reader is referred to Stiles et al. (2013).

QuikSCAT was a NASA Earth-observing satellite carrying the SeaWinds scatterometer. QuikSCAT followed a sun-synchronous orbit at an altitude of 802 km and at a speed of approximately 7 km per second, with equatorial crossing times of ascending swaths at about 06:00 LST ±30 minutes. Along the equator, consecutive swaths are separated by 2,800 km. The scatterometric data swath is centered on the satellite ground track with no nadir gap. SeaWinds used a rotating dish antenna with two spot beams that sweep in a circular pattern. It radiated 110 W microwave pulses at a pulse repetition frequency (PRF) of 189 Hz, operating at a frequency of 13.4 GHz, which is in the Ku-band of microwave frequencies. At this frequency, the atmosphere is mostly transparent to non-precipitating clouds and aerosols, although rain produces significant alteration of the signal. Because of its wide swath and lack of in-swath gaps, QuikSCAT was able to collect at least one vector wind measurement over 93% of the Earth's oceans each day.

For complete details on the original QuikSCAT measurement data, the reader is referred to Hoffman and Leidner (2005).

In addition to wind vector data, the JPL database also includes a quantity proportional to rain rate (hereafter "rain rate"; not accurate for absolute rain rates), as well as cloud liquid data on the same grid. Estimates of rain rate are calculated based on brightness temperature measurements from the SeaWinds radiometer aboard the QuikSCAT satellite (Ahmad et al. 2005). Furthermore, JPL has added to the database collocated cloud liquid content data from the SSM/I passive microwave radiometer at all gridpoints and times where data are available sufficiently close to QuikSCAT data in space and time, though these data may contain colocation errors.

For rain rates, data coverage is identical to that of the wind vector data, with one exception: in the vicinity of the coastline, rain rates equal zero artificially. This is a known issue in the JPL dataset that has yet to be addressed. For the construction of the current version of the QSCAT-R dataset, we first remove all rain rate data within 100km of the coast to crudely account for this problem. Once the JPL dataset is updated to properly account for this issue, the QSCAT-R dataset will be updated accordingly in a future release.

For SSM/I cloud data, coverage depends on proximity of the SSM/I swath to that of QuikSCAT, and thus varies on a case-by-case basis.

For complete details on the QuikSCAT radiometric estimates of precipitation rate, the reader is referred to Ahmad et al. (2005).

IBTrACS Best Track Database: HURDAT2 and JTWC

The International Best Track Archive for Climate Stewardship (IBTrACS; http://www.ncdc.noaa.gov/ibtracs/) is used as the central source of "Best Track" storm lifecycle data for track and intensity globally. The IBTrACS dataset provides Best Track information from all available source agencies ('IBTrACS-All') and provides a unique serial name identifier for each storm in the database. For the construction of the QSCAT-R dataset, the National Hurricane Center (NHC) HURDAT2 Best Track database is used as the source for storms in the North Atlantic and East Pacific basins ('hurdat_atl' and 'hurdat_epa', respectively), while the United States Joint Typhoon Warning Center (JTWC) Best Track database is used as the source for storms in all other basins (Central Pacific, West Pacific, Indian Ocean, and Southern Hemisphere: 'jtwc_cp', 'jtwc_wp', 'jtwc_io', 'jtwc_sh', respectively). JTWC data are selected because they represent a comparable Best Track to that of NHC HURDAT2, as both use a common wind averaging time period and similar intensity estimation and center finding methods. Moreover, both NHC and JTWC employ the Automated Tropical Cylcone Forecasting (ATCF) system.

The Best Track parameters used herein are:

- Position of the storm center (lat/lon),
- Maximum sustained surface wind speed (Vmax, otherwise known as 'Intensity'),
- Minimum central pressure (Pmin).

IBTrACS version v03r05 is employed here, accessed 3 December 2013.

Description of QSCAT-R dataset: One File Per Storm

File Naming Convention

The naming convention for each individual storm data file is: ***<atcf_id>_<atcf_name>_<ibtracs_id>*.nc**, where *<atcf_id>* is the official ATCF storm identification code (format: *<basin_code><storm_number><year>*), *<atcf_name>* is the ATCF storm name, and *<ibtracs_id>* is the official IBTrACS storm identification code (format: *<year_of_formation><day_of_formation><hemisphere_of_formation><latitude_of_formation_rounded><longitude_of_formation_rounded>*). For example, the naming convention for the file for Katrina (2005) is AL122005_KATRINA_2005236N23285.nc, where its ATCF storm ID is "AL122005" and its IBTrACS ID is "2005236N23285", indicating that it formed in 2005 on day 236 in the Northern Hemisphere at approximately 23N and 285E.

A storm number value of "00" (e.g. WP001954_*<atcf_name>*_*<ibtracs_id>*.nc) indicates that no official storm ID was available.

Note: In a few limited occasions, IBTrACS merges two tracks into one when the storms were originally classified as distinct but upon reanalysis determined to be a single storm. Example: IBTrACS ID 2000193N10131 combines WP072000 and WP082000 from the JTWC database (ftp://eclipse.ncdc.noaa.gov/pub/ibtracs/v03r05/maps/all_maps/2000193N10131.png). In such cases, the first ATCF storm ID listed is used.

File Type

All data files are provided in fully self-describing NetCDF format following NetCDF version 4.1.3. Files were created using MATLAB R2014a and should be readable by any NetCDF-enabled data analysis program.

Data Parameters

Within each file there are three groups of parameters, following standard NetCDF structure:
(1) Global attributes: descriptive parameters for the file and the storm
(2) Dimensions: parameters defining data matrix dimensions
(3) Variables: the primary data

(1) *Global attributes:* General, file-level and storm-level descriptive data. One entry per file.

Global attributes describing the file:
title: brief description of file
institution: location of file creation
history: additional information about file

source: information on the raw JPL datafiles from which the QSCAT-R data are derived
references: information on governing project for dataset
comment: information on file source data
ProjectName: name of governing project
ProjectSponsor: sponsor of governing project
Investigator: file creator
Contributors: all contributors to file creation
Acknowledgments: broader thanks to those whose work underlies this file
DataUsagePolicy: information on end use of this dataset and proper citation by the user
DatasetRestrictions: commercial and other restrictions on use and dissemination of dataset
Email: email of Investigator
CodeVersionUsedForProcessing: code type and version for file creation
Conventions: netCDF convention standard for file
Conventions_detail: details for Conventions
DateProcessed: date/time of file creation (automatically-generated)

Global attributes describing the storm:
StormID_ATCF: storm ID used in ATCF systems (HURDAT2 or JTWC)
StormID_IBTrACS: storm ID as given by IBTrACS
StormName: storm name used in ATCF datasets (HURDAT2 or JTWC)
StormYear: year in which the storm formed, as used in ATCF datasets (HURDAT2 or JTWC)
StormBasin: two-letter basin code (e.g. 'AL')
NumberGoodQSFixes: number of timesteps with valid QuikSCAT data included in file (file only exists if there is at least one valid QuikSCAT fix)
start_time: date/time of earliest QuikSCAT timestep in file (format: YYYYMMDDHHMMSS)
end_time: date/time of latest QuikSCAT timestep in file (format: YYYYMMDDHHMMSS)

(2) *Dimensions*: Parameters describing the dimensions of the Variables. One entry per file.

datetime_len: number of characters needed for the variable 'date_time' in format YYYYMMDDHHMMSS
QS_nwindradii: number of wind radii entries recorded (currently equals 4: radii of 64 kt, 50 kt, 34 kt, and 23.3 kt (12 m/s))
QS_npasses: number of timesteps with valid QuikSCAT data (same as 'NumberGoodQSFixes')
QS_nradial_grid_points: number of radial gridpoints in radial profile data

(3) *Variables:* Data for each variable across all available timesteps during the storm lifecycle (vector or matrix). The matrix dimensions of the variable are defined in terms of the dimension parameters listed above. General parameters for each QuikSCAT pass carry the prefix **QS_PASS**; parameters for discrete wind radii carry the prefix **QS_WR**; and parameters for radial profiles carry the prefix **QS_RP**.

QS_PASS_date_time: Human-readable date and time (format: \'YYYYMMDDHHMMSS\', in UTC) of each QuikSCAT pass, as given in the JPL database. Time corresponds to time of minimum distance to storm center.

QS_PASS_timeoffset: Universal time variable in seconds since 1970 01 01 0000 UTC (Unix standard).

QS_PASS_time_sec_sincefirstQSobs: Time in seconds since the initial QuikSCAT obs point in the file.

QS_PASS_time_sec_sinceBTgenesis: Time in seconds since genesis, defined as time of first datapoint in Best Track.

QS_PASS_latitude: Interpolated Best Track latitude (degrees north [-90 90]) at each QuikSCAT pass time. Interpolation performed using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP).

QS_PASS_longitude: Interpolated Best Track longitude (degrees east [-180,180)) at each QuikSCAT pass time. Interpolation performed using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP).

QS_PASS_vmax: Interpolated Best Track storm peak wind speed at each QuikSCAT pass time. Interpolation performed using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP).

QS_PASS_pmin: Interpolated Best Track storm minimum central sea-level pressure at each QuikSCAT pass time. Interpolation performed using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP).

QS_PASS_zonal_translation_speed: Zonal component of translation vector of interpolated Best Track TC center at each QuikSCAT pass time. Interpolation performed using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP).

QS_PASS_meridional_translation_speed: Meridional component of translation vector of interpolated Best Track TC center at each QuikSCAT pass time. Interpolation performed using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP).

QS_WR_wind_speed_thresholds: Wind speeds at which wind radii (QS_WR_total_wind_speed and QS_WR_azimuthal_wind_speed) are calculated; positive = cyclonic (CCW in NH).

QS_WR_total_wind_speed: Radii of input total wind speeds (QS_WR_wind_speed_thresholds). Calculated from radial profile of the azimuthal-mean of the total wind, for all available QuikSCAT data. See below for details, including discussion of uncertainties in these data. Users should verify values against radial profile of interest.

QS_WR_azimuthal_wind_speed: Radii of input azimuthal wind speeds (QS_WR_wind_speed_thresholds). Calculated from radial profile of the azimuthal-mean of the azimuthal (rotating) component of the wind, for all available QuikSCAT data. See below for details, including discussion of uncertainties in these data. Users should verify values against radial profile of interest.

QS_WR_total_wind_speed_asymmetry_parameter: Local value of azimuthal asymmetry parameter at wind radii given by QS_WR_total_wind_speed; range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each radial grid point; it is defined as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in the radial bin, normalized by mean bin radius. See below for details.

QS_WR_azimuthal_wind_speed_asymmetry_parameter: Local value of azimuthal asymmetry parameter at wind radii given by QS_WR_azimuthal_wind_speed; range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each radial grid point; it is defined as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in the radial bin, normalized by mean bin radius. See below for details.

QS_WR_total_maximum_wind_speed_threshold: Maximum total wind -- NOT RECOMMENDED FOR DIRECT ANALYSIS. Calculated from radial profile of the azimuthal-mean of the total wind, for all available QuikSCAT data prior to regridding. See below for details, including discussion of uncertainties in these data. Users should verify values against radial profile of interest.

QS_WR_azimuthal_maximum_wind_speed_threshold: Maximum azimuthal wind -- NOT RECOMMENDED FOR DIRECT ANALYSIS. Calculated from radial profile of the azimuthal-mean of the azimuthal (rotating) component of the wind, for all available QuikSCAT data prior to regridding. See below for details, including discussion of uncertainties in these data. Users should verify values against radial profile of interest.

QS_WR_total_maximum_wind_speed: Radius of maximum total wind given by QS_WR_total_maximum_wind_speed_threshold -- NOT RECOMMENDED FOR DIRECT ANALYSIS. Calculated from radial profile of the azimuthal-mean of the total wind, for all available QuikSCAT data. See below for details, including discussion of uncertainties in these data. Users should verify values against radial profile of interest.

QS_WR_azimuthal_maximum_wind_speed: Radius of maximum azimuthal wind given by QS_WR_azimuthal_maximum_wind_speed_threshold -- NOT RECOMMENDED FOR DIRECT ANALYSIS. Calculated from radial profile of the azimuthal-mean of the azimuthal (rotating) component of the wind, for all available QuikSCAT data. See below for details, including discussion of uncertainties in these data. Users should verify values against radial profile of interest.

QS_WR_total_maximum_wind_speed_asymmetry_parameter: Local value of azimuthal asymmetry parameter at radius of maximum total wind (QS_WR_total_maximum_wind_speed); range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each radial grid point; it is defined as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in the radial bin, normalized by mean bin radius. See below for details.

QS_WR_azimuthal_maximum_wind_speed_asymmetry_parameter: Local value of azimuthal asymmetry parameter at radius of maximum azimuthal wind (QS_WR_azimuthal_maximum_wind_speed); range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each radial grid point; it is defined as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in the radial bin, normalized by mean bin radius. See below for details.

QS_RP_radius_coordinate: Gridded radial coordinate used in radial profiles. Values range from 3.125 to 1996.875 km in regular increments of dr = 6.25 km.

QS_RP_total_wind_speed: Radial profile of azimuthal-mean total wind speed along radial grid (QS_RP_radius_coordinate); positive definite quantity. See below for details, including discussion of uncertainties in these data.

QS_RP_azimuthal_wind_speed: Radial profile of azimuthal-mean azimuthal (rotating) wind speed along radial grid (QS_RP_radius_coordinate); positive = cyclonic (CCW in NH). Not recommended for use at small radii in the vicinity of the radius of maximum winds. See below for details, including discussion of uncertainties in these data.

QS_RP_radial_wind_speed: Radial profile of azimuthal-mean radial wind speed along radial grid (QS_RP_radius_coordinate); positive = outwards. Not recommended for use at small radii in the vicinity of the radius of maximum winds. See below for details, including discussion of uncertainties in these data.

QS_RP_asymmetry_parameter: Radial profile of wind data azimuthal asymmetry parameter along radial grid (QS_RP_radius_coordinate); range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each radial grid point; it is defined as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in the radial bin, normalized by mean bin radius. See below for details.

QS_RP_rainrate: Radial profile of azimuthal-mean precipitation rate (proportional to mm/hr) along radial grid (QS_RP_radius_coordinate). Quantity scales with precipitation rate and is not accurate as an absolute quantity. See below for details.

QS_RP_asymmetry_parameter_rainrate: Radial profile of rain rate data azimuthal asymmetry parameter along radial grid (QS_RP_radius_coordinate); range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each radial grid point; it is defined as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in the radial bin, normalized by mean bin radius. See below for details.

QS_RP_cloudssmi: Radial profile of azimuthal-mean cloud liquid (g/kg) along radial grid (QS_RP_radius_coordinate), from collocated SSM/I data as provided in JPL database. See below for details.

QS_RP_asymmetry_parameter_cloud: Radial profile of cloud data azimuthal asymmetry parameter along radial grid (QS_RP_radius_coordinate); range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each radial grid point; it is defined as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in the radial bin, normalized by mean bin radius. See below for details.

Each variable has a structure that is characterized by its

1) datatype (e.g. char, double), and
2) size, defined by its prescribed dimensions (e.g. <*QS_npasses*> x <*datetime_len*>).

Additionally, each variable carries with it up to three attributes:

1) **units**: dimensional units of variable (numeric datatypes only). SI units used, except for pressure given in hPa
2) **_FillValue**: indicator of missing data. "-9999" used in all cases
3) **long_name**: description of variable

In a standard terminal, a full listing of the above parameters for a given file may be obtained by using the *ncdump* command with the –h option (e.g., 'ncdump –h <filename.nc>').

Time: Two Formats

Time information is provided in two distinct formats:

1) Traditional date format ("**QS_PASS_date_time**"): a string of the format 'YYYYMMDDHHMMSS' that represents the 4-digit year 'YYYY', the 2-digit month 'MM', the 2-digit day 'DD', the 2-digit hour 'HH', the 2-digit minute 'MM', and the 2-digit second 'SS' that corresponds to the time (UTC) of the parameter value.
2) Universal time format ("**QS_PASS_timeoffset**"): the number of seconds since a standard base time, taken as 1970-01-01 00:00:00 UTC. This format increases uniformly with time, allowing for convenient analysis of data across multiple timesteps. Two additional versions provide the number of seconds since the earliest time in the file ("**QS_PASS_time_sec_sincefirstQSobs**") and the number of seconds since the Best Track genesis ("**QS_PASS_time_sec_sinceBTgenesis**").

Fill Values

To indicate missing data, a "Fill Value" of -9999 is used for all numeric data.

Units

In all cases SI units are used (e.g. meters, meters per second), with the exception of pressure given in the meteorological standard unit hPa.

Illustrative Example: AL122005_KATRINA_2005236N23285.nc

An illustrative example is provided below, which shows the output from the terminal command '**ncdump –h AL122005_KATRINA_2005236N23285.nc**' with explanatory in-line comments in blue:

netcdf AL122005_KATRINA_2005236N23285 {

The file name.

dimensions:

datetime_len = 14 ;
QS_nwindradii = 4 ;
QS_npasses = 17 ;
QS_nradial_grid_points = 320 ;

The file includes data from 17 valid QuikSCAT passes (‘QS_npasses’) and has 4 wind radii included (‘QS_nwindradii’). Radial profile data are provided on a grid with 320 radial gridpoints (‘QS_nradial_grid_points’); which grid points contain valid data varies from case to case depending on data availability. A date-time entry requires 14 characters (‘datetime_len’).

variables:

char QS_PASS_date_time(QS_npasses, datetime_len) ;
QS_PASS_date_time:long_name = "Human-readable date and time (format: \'YYYYMMDDHHMMSS\', in UTC) of each QuikSCAT pass, as given in the JPL database. Time corresponds to time of minimum distance to storm center." ;

The above variable, ‘QS_PASS_date_time’, is a two dimensional matrix of size <*datetime_len*> x <*QS_npasses*> and datatype ‘char’ that contains the date/time (format YYYYMMDDHHMMSS, along the first matrix dimension) corresponding to each of the <*QS_npasses*> available QuikSCAT passes (along the second matrix dimension). There are never missing values, and thus no Fill Value is provided.

double QS_PASS_timeoffset(QS_npasses) ;
QS_PASS_timeoffset:units = "sec" ;
QS_PASS_timeoffset:_FillValue = -9999. ;
QS_PASS_timeoffset:long_name = "Universal time variable in seconds since 1970 01 01 0000 UTC (Unix standard)" ;
double QS_PASS_time_sec_sincefirstQSobs(QS_npasses) ;
QS_PASS_time_sec_sincefirstQSobs:units = "sec" ;
QS_PASS_time_sec_sincefirstQSobs:_FillValue = -9999. ;
QS_PASS_time_sec_sincefirstQSobs:long_name = "Time in seconds since the initial QuikSCAT obs point in the file" ;
double QS_PASS_time_sec_sinceBTgenesis(QS_npasses) ;
QS_PASS_time_sec_sinceBTgenesis:units = "sec" ;
QS_PASS_time_sec_sinceBTgenesis:_FillValue = -9999. ;
QS_PASS_time_sec_sinceBTgenesis:long_name = "Time in seconds since genesis, defined as time of first datapoint in Best Track." ;
double QS_PASS_latitude(QS_npasses) ;
QS_PASS_latitude:units = "degrees_north" ;
QS_PASS_latitude:_FillValue = -9999. ;
QS_PASS_latitude:long_name = "Interpolated Best Track latitude (degrees north [-90 90]) at each QuikSCAT pass time. Interpolation performed using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP)." ;

The above variable, ‘QS_PASS_latitude’, is a one dimensional vector of length <*QS_npasses*> and datatype ‘double’ that contains the latitude (in units of deg N) of the interpolated Best Track storm center at each of the <*QS_npasses*> timesteps in the file. If there are missing data, they will be represented with a value of ‘-9999’.

double QS_PASS_longitude(QS_npasses) ;
QS_PASS_longitude:units = "degrees_east" ;
QS_PASS_longitude:_FillValue = -9999. ;
QS_PASS_longitude:long_name = "Interpolated Best Track longitude (degrees east [-180,180)) at each QuikSCAT pass time. Interpolation performed using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP)." ;
double QS_PASS_vmax(QS_npasses) ;
QS_PASS_vmax:units = "m/s" ;
QS_PASS_vmax:_FillValue = -9999. ;
QS_PASS_vmax:long_name = "Interpolated Best Track storm peak wind speed at each QuikSCAT pass time. Interpolation performed using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP)." ;
double QS_PASS_pmin(QS_npasses) ;
QS_PASS_pmin:units = "hPa" ;
QS_PASS_pmin:_FillValue = -9999. ;
QS_PASS_pmin:long_name = "Interpolated Best Track storm minimum central sea-level pressure at each QuikSCAT pass time. Interpolation performed using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP)." ;
double QS_PASS_zonal_translation_speed(QS_npasses) ;
QS_PASS_zonal_translation_speed:units = "m/s" ;
QS_PASS_zonal_translation_speed:_FillValue = -9999. ;
QS_PASS_zonal_translation_speed:long_name = "Zonal component of translation vector of interpolated Best Track TC center at each QuikSCAT pass time. Interpolation performed using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP)." ;
double QS_PASS_meridional_translation_speed(QS_npasses) ;
QS_PASS_meridional_translation_speed:units = "m/s" ;
QS_PASS_meridional_translation_speed:_FillValue = -9999. ;
QS_PASS_meridional_translation_speed:long_name = "Meridional component of translation vector of interpolated Best Track TC center at each QuikSCAT pass time. Interpolation performed using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP)." ;
double QS_WR_wind_speed_thresholds(QS_npasses, QS_nwindradii) ;
QS_WR_wind_speed_thresholds:units = "m/s" ;
QS_WR_wind_speed_thresholds:_FillValue = -9999. ;
QS_WR_wind_speed_thresholds:long_name = "Wind speeds at which wind radii (QS_WR_azimuthal_wind_speed) are calculated; positive = cyclonic (CCW in NH)" ;
double QS_WR_total_wind_speed(QS_npasses, QS_nwindradii) ;
QS_WR_total_wind_speed:units = "m" ;
QS_WR_total_wind_speed:_FillValue = -9999. ;
QS_WR_total_wind_speed:long_name = "Radii of input total wind speeds (QS_WR_wind_speed_thresholds). Calculated from radial profile of the azimuthal-mean of the total wind, for all available QuikSCAT data. See documentation for details, including discussion of uncertainties in these data. Users should verify values against radial profile of interest." ;
double QS_WR_azimuthal_wind_speed(QS_npasses, QS_nwindradii) ;
QS_WR_azimuthal_wind_speed:units = "m" ;
QS_WR_azimuthal_wind_speed:_FillValue = -9999. ;
QS_WR_azimuthal_wind_speed:long_name = "Radii of input azimuthal wind speeds (QS_WR_wind_speed_thresholds). Calculated from radial profile of the azimuthal-mean of the azimuthal (rotating) component of the wind, for all available QuikSCAT data. See documentation for details, including discussion of uncertainties in these data. Users should verify values against radial profile of interest." ;
double QS_WR_total_wind_speed_asymmetry_parameter(QS_npasses, QS_nwindradii) ;
QS_WR_total_wind_speed_asymmetry_parameter:units = "nondimensional" ;
QS_WR_total_wind_speed_asymmetry_parameter:_FillValue = -9999. ;

QS_WR_total_wind_speed_asymmetry_parameter:long_name = "Local value of azimuthal asymmetry parameter at wind radii given by QS_WR_total_wind_speed; range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each radial grid point; it is defined as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in radial bin, normalized by mean bin radius. See documentation for details." ;

double QS_WR_azimuthal_wind_speed_asymmetry_parameter(QS_npasses, QS_nwindradii) ;

QS_WR_azimuthal_wind_speed_asymmetry_parameter:units = "nondimensional" ;

QS_WR_azimuthal_wind_speed_asymmetry_parameter:_FillValue = -9999. ;

QS_WR_azimuthal_wind_speed_asymmetry_parameter:long_name = "Local value of azimuthal asymmetry parameter at wind radii given by QS_WR_azimuthal_wind_speed; range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each radial grid point; it is defined as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in radial bin, normalized by mean bin radius. See documentation for details." ;

double QS_WR_total_maximum_wind_speed_threshold(QS_npasses) ;

QS_WR_total_maximum_wind_speed_threshold:units = "m" ;

QS_WR_total_maximum_wind_speed_threshold:_FillValue = -9999. ;

QS_WR_total_maximum_wind_speed_threshold:long_name = "Maximum total wind -- NOT RECOMMENDED FOR DIRECT ANALYSIS. Calculated from radial profile of the azimuthal-mean of the total wind, for all available QuikSCAT data prior to regridding. See documentation for details, including discussion of uncertainties in these data. Users should verify values against radial profile of interest." ;

double QS_WR_azimuthal_maximum_wind_speed_threshold(QS_npasses) ;

QS_WR_azimuthal_maximum_wind_speed_threshold:units = "m" ;

QS_WR_azimuthal_maximum_wind_speed_threshold:_FillValue = -9999. ;

QS_WR_azimuthal_maximum_wind_speed_threshold:long_name = "Maximum azimuthal wind -- NOT RECOMMENDED FOR DIRECT ANALYSIS. Calculated from radial profile of the azimuthal-mean of the azimuthal (rotating) component of the wind, for all available QuikSCAT data prior to regridding. See documentation for details, including discussion of uncertainties in these data. Users should verify values against radial profile of interest." ;

double QS_WR_total_maximum_wind_speed(QS_npasses) ;

QS_WR_total_maximum_wind_speed:units = "m" ;

QS_WR_total_maximum_wind_speed:_FillValue = -9999. ;

QS_WR_total_maximum_wind_speed:long_name = "Radius of maximum total wind given by QS_WR_total_maximum_wind_speed_threshold -- NOT RECOMMENDED FOR DIRECT ANALYSIS. Calculated from radial profile of the azimuthal-mean of the total wind, for all available QuikSCAT data. See documentation for details, including discussion of uncertainties in these data. Users should verify values against radial profile of interest." ;

double QS_WR_azimuthal_maximum_wind_speed(QS_npasses) ;

QS_WR_azimuthal_maximum_wind_speed:units = "m" ;

QS_WR_azimuthal_maximum_wind_speed:_FillValue = -9999. ;

QS_WR_azimuthal_maximum_wind_speed:long_name = "Radius of maximum azimuthal wind given by QS_WR_azimuthal_maximum_wind_speed_threshold -- NOT RECOMMENDED FOR DIRECT ANALYSIS. Calculated from radial profile of the azimuthal-mean of the azimuthal (rotating) component of the wind, for all available QuikSCAT data. See documentation for details, including discussion of uncertainties in these data. Users should verify values against radial profile of interest." ;

double QS_WR_total_maximum_wind_speed_asymmetry_parameter(QS_npasses) ;

QS_WR_total_maximum_wind_speed_asymmetry_parameter:units = "nondimensional" ;

QS_WR_total_maximum_wind_speed_asymmetry_parameter:_FillValue = -9999. ;

QS_WR_total_maximum_wind_speed_asymmetry_parameter:long_name = "Local value of azimuthal asymmetry parameter at radius of maximum total wind (QS_WR_total_maximum_wind_speed); range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each radial grid point; it is defined

as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in radial bin, normalized by mean bin radius. See documentation for details." ;
double QS_WR_azimuthal_maximum_wind_speed_asymmetry_parameter(QS_npasses) ;
QS_WR_azimuthal_maximum_wind_speed_asymmetry_parameter:units = "nondimensional" ;
QS_WR_azimuthal_maximum_wind_speed_asymmetry_parameter:_FillValue = -9999. ;
QS_WR_azimuthal_maximum_wind_speed_asymmetry_parameter:long_name = "Local value of azimuthal asymmetry parameter at radius of maximum azimuthal wind (QS_WR_azimuthal_maximum_wind_speed); range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each radial grid point; it is defined as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in radial bin, normalized by mean bin radius. See documentation for details." ;
double QS_RP_radius_coordinate(QS_nradial_grid_points) ;
QS_RP_radius_coordinate:units = "m" ;
QS_RP_radius_coordinate:_FillValue = -9999. ;
QS_RP_radius_coordinate:long_name = "Gridded radial coordinate used in radial profiles. Values range from 3.12 to 1996.88 km in regular increments of dr = 6.25 km" ;
double QS_RP_total_wind_speed(QS_npasses, QS_nradial_grid_points) ;
QS_RP_total_wind_speed:units = "m/s" ;
QS_RP_total_wind_speed:_FillValue = -9999. ;
QS_RP_total_wind_speed:long_name = "Radial profile of azimuthal-mean total wind speed along radial grid (QS_RP_radius_coordinate); positive definite quantity. See documentation for details, including discussion of uncertainties in these data." ;
double QS_RP_azimuthal_wind_speed(QS_npasses, QS_nradial_grid_points) ;
QS_RP_azimuthal_wind_speed:units = "m/s" ;
QS_RP_azimuthal_wind_speed:_FillValue = -9999. ;
QS_RP_azimuthal_wind_speed:long_name = "Radial profile of azimuthal-mean azimuthal (rotating) wind speed along radial grid (QS_RP_radius_coordinate); positive = cyclonic (CCW in NH). Not recommended for use at small radii in the vicinity of the radius of maximum winds. See documentation for details, including discussion of uncertainties in these data." ;

The above variable, 'QS_RP_azimuthal_wind_speed', is a two dimensional matrix of size <*QS_npasses*> x <*QS_nradial_grid_points*> and datatype 'double' that contains the radial profile of the azimuthal-mean azimuthal wind speed (in units of m/s) at each timestep (along the first matrix dimension) on the radial coordinate grid defined by 'QS_RP_radius_coordinate' (along the second matrix dimension). If there are missing data, they will be represented with a value of '-9999'.

double QS_RP_radial_wind_speed(QS_npasses, QS_nradial_grid_points) ;
QS_RP_radial_wind_speed:units = "m/s" ;
QS_RP_radial_wind_speed:_FillValue = -9999. ;
QS_RP_radial_wind_speed:long_name = "Radial profile of azimuthal-mean radial wind speed along radial grid (QS_RP_radius_coordinate); positive = outwards. Not recommended for use at small radii in the vicinity of the radius of maximum winds. See documentation for details, including discussion of uncertainties in these data." ;
double QS_RP_asymmetry_parameter(QS_npasses, QS_nradial_grid_points) ;
QS_RP_asymmetry_parameter:units = "nondimensional" ;
QS_RP_asymmetry_parameter:_FillValue = -9999. ;
QS_RP_asymmetry_parameter:long_name = "Radial profile of wind data azimuthal asymmetry parameter along radial grid (QS_RP_radius_coordinate); range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each

radial grid point; it is defined as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in radial bin, normalized by mean bin radius. See documentation for details." ;

double QS_RP_rainrate(QS_npasses, QS_nradial_grid_points) ;

QS_RP_rainrate:units = "proportional to mm/hr" ;

QS_RP_rainrate:_FillValue = -9999. ;

QS_RP_rainrate:long_name = "Radial profile of azimuthal-mean precipitation rate (proportional to mm/hr) along radial grid (QS_RP_radius_coordinate). Quantity scales with precipitation rate and is not accurate as an absolute quantity. See documentation for details." ;

double QS_RP_asymmetry_parameter_rainrate(QS_npasses, QS_nradial_grid_points) ;

QS_RP_asymmetry_parameter_rainrate:units = "nondimensional" ;

QS_RP_asymmetry_parameter_rainrate:_FillValue = -9999. ;

QS_RP_asymmetry_parameter_rainrate:long_name = "Radial profile of rain rate data azimuthal asymmetry parameter along radial grid (QS_RP_radius_coordinate); range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each radial grid point; it is defined as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in radial bin, normalized by mean bin radius. See documentation for details." ;

double QS_RP_cloudssmi(QS_npasses, QS_nradial_grid_points) ;

QS_RP_cloudssmi:units = "g/kg" ;

QS_RP_cloudssmi:_FillValue = -9999. ;

QS_RP_cloudssmi:long_name = "Radial profile of azimuthal-mean cloud liquid (g/kg) along radial grid (QS_RP_radius_coordinate), from collocated SSM/I data as provided in JPL database (colocation errors possible). See documentation for details." ;

double QS_RP_asymmetry_parameter_cloud(QS_npasses, QS_nradial_grid_points) ;

QS_RP_asymmetry_parameter_cloud:units = "nondimensional" ;

QS_RP_asymmetry_parameter_cloud:_FillValue = -9999. ;

QS_RP_asymmetry_parameter_cloud:long_name = "Radial profile of SSM/I cloud data azimuthal asymmetry parameter along radial grid (QS_RP_radius_coordinate); range is [0,1], where 0 = perfect symmetry (low uncertainty) and 1 = perfect asymmetry (high uncertainty). Asymmetry parameter is a measure of the azimuthal asymmetry of data coverage used to calculate the azimuthal-mean at each radial grid point; it is defined as the magnitude of the vector mean of the set of vectors from storm center to all valid gridpoints included in radial bin, normalized by mean bin radius. See documentation for details." ;

// global attributes:

:title = "Wind radii and radial profiles of wind and rain for tropical cyclone KATRINA (2005) from QuikSCAT version 3 database (http://tropicalcyclone.jpl.nasa.gov/)" ;

:institution = "Princeton University, Department of Civil and Environmental Engineering (CEE)" ;

:history = "2014-08-27 17:19:55 data file created using MATLAB 8.3.0.532 (R2014a) running AA4_QuikSCAT_mat2nc.m" ;

:source = "Retrieved wind data from the QuikSCAT satellite via NASA Jet Propulsion Laboratory (JPL) FTP server ftp://mwsci.jpl.nasa.gov/outgoing/data/quikscat/KATRINA/2005/north_atlantic/SEAWINDS_QUIKSCAT_L2_WIND_[YEAR][MONTH][DAY]_[HOUR][MIN].nc" ;

:references = "Tropical Cyclone Data Project web site: http://verif.rap.ucar.edu/tcdata/quikscat/" ;

:comment = "Original source data: NASA Jet Propulsion Laboratory (JPL) QuikSCAT Global Wind Vector Database (Version 3) database (http://tropicalcyclone.jpl.nasa.gov/). See documentation for full details." ;

:ProjectName = "Tropical Cyclone Data Project: Development of an Improved Database of Tropical Cyclone Size Parameters" ;

:ProjectSponsor = "Risk Prediction Initiative (2.0), Bermuda Institute of Ocean Sciences (BIOS)" ;

:Investigator = "Daniel R. Chavas, PhD" ;
:Contributors = "The QuikSCAT radial profile database was created by Daniel R. Chavas, PhD. Considerable help with file and data formatting was provided by Dr. Jonathan Vigh (NCAR/RAL/JNT). Great assistance was also provided by Bryan Stiles, Svetla Hristova-Veleva and their team at the NASA Jet Propulsion Laboratory (JPL) in both developing the raw QuikSCAT Tropical Cyclone dataset for the world and helping with issues in data access, structure, and type needed for the creation of this radial profile dataset." ;
:Acknowledgments = "Tremendous gratitude is given to the folks at NASA and the NASA Jet Propulsion Laboratory for their hard work in developing and launching the QuikSCAT satellite and its instruments, for creating, maintaining and quality-controlling the entire database of wind and rain products derived from its measurements, and for further developing a specialized product designed specifically for tropical cyclones. This is an incredibly useful and bountiful dataset that offers the potential for tremendous insight into the structure and physics of tropical cyclones for decades to come. We hold out hope that someday a new QuikSCAT will be funded that can provide a continuous feed of high-quality observations to improve our understanding of the science of tropical cyclones and their predictability for the betterment of society." ;
:DataUsagePolicy = "We ask that proper acknowledgments be made to the NCAR Tropical Cyclone Data Project, Princeton University, the NASA Jet Propulsion Laboratory (JPL), and the Risk Prediction Initative (RPI2.0) for the use of these data in any publications or presentations.If any data from the QSCAT-R data set are used in a scientific paper, please cite the relevant publication(s) of the development scientist, Dr. Daniel Chavas. If use of QSCAT-R data in a publication constitutes a major or fairly significant aspect of an article, co-authorship is appropriate; please discuss any such planned use with Dr. Daniel Chavas. If you do cite our work in a publication, please send a reprint or an email with the citation, so that we might keep track of the use of our work. Thank you in advance." ;
:DatasetRestrictions = "Until this dataset is publicly released, no commercial uses are allowed except by member companies of the Risk Prediction Intiaitive (RPI2.0). This restriction will expire upon the public release of the dataset, currently scheduled for sometime in 2015." ;
:Email = "drchavas@gmail.com" ;
:CodeVersionUsedForProcessing = "MATLAB 8.3.0.532 (R2014a)" ;
:Conventions = "CF-1.6" ;
:Conventions_detail = "NetCDF Climate and Forecast (CF) Metadata Conventions, Version 1.6, 05 December, 2011: http://cf-pcmdi.llnl.gov/documents/cf-conventions/1.6/cf-conventions.html" ;
:DateProcessed = "2014-08-27 17:19:55" ;
:StormID_ATCF = "AL122005" ;
:StormID_IBTrACS = "2005236N23285" ;
:StormName = "KATRINA" ;
:StormYear = "2005" ;
:StormBasin = "AL" ;
:NumberGoodQSFixes = 17. ;
:start_time = 20050823223900. ;
:end_time = 20050831003400. ;

This file provides data for Hurricane Katrina in 2005 in the Atlantic Basin, with ATCF ID ‘AL122005’ and IBTrACS ID ‘2005236N23285’. The file includes 17 distinct QuikSCAT passes between 2239 UTC 23 Aug 2005 and 0034 UTC 31 Aug 2005.

}

Methodology: How the Parameters are Calculated

Global Storm-Level Attributes

Global attributes: **StormID_IBTrACS, StormYear, StormName, StormID_ATCF**

The general storm parameters **StormID_IBTrACS**, **StormYear**, and **StormName** are extracted from the IBTrACS-All database. The National Hurricane Center (NHC) HURDAT2 Best Track database is used as the source for storms in the North Atlantic and East Pacific basins (‘hurdat_atl’ and ‘hurdat_epa’, respectively), while the United States Joint Typhoon Warning Center (JTWC) Best Track database is used as the source for storms in all other basins (Central Pacific, West Pacific, Indian Ocean, and Southern Hemisphere: 'jtwc_cp', 'jtwc_wp', 'jtwc_io', 'jtwc_sh', respectively). Meanwhile, **StormID_ATCF** is extracted from the IBTrACS storm-specific netCDF files to map the aforementioned IBTrACS general storm parameters to the same storm in the ATCF Best Track archive.

StormID_ATCF has the format “*<basin_code><storm_number><year>*” (e.g. AL122005) and **StormID_IBTrACS** uses “*<year_of_formation><day_of_formation><hemisphere_of_formation><latitude_of_formation_rounded><longitude_of_formation_rounded>*” (e.g. 2005236N23285).

Date/Time Data

Variables: **QS_PASS_date_time, QS_PASS_timeoffset, QS_PASS_time_sec_sincefirstQSobs, QS_PASS_time_sec_sinceBTgenesis**

The **QS_PASS_date_time** variable for each QuikSCAT pass is taken directly from the NASA JPL QuikSCAT Tropical Cyclone database file. This time corresponds to the JPL-estimated time of closest passage of the QuikSCAT satellite to the storm center. Because of the rapid motion of the QuikSCAT satellite (7 km s^{-1}), all measurements in each raw JPL data file (i.e. in the vicinity of the storm) are taken within a time span of less than 10 minutes, and thus all data within a given QuikSCAT pass are effectively concurrent.

Universal time variables are subsequently calculated from the traditional time variable using the MATLAB function ‘datenum’.

Best Track Storm Data

Variables: **QS_PASS_latitude, QS_PASS_longitude, QS_PASS_vmax, QS_PASS_pmin**, **QS_PASS_zonal_translation_speed, QS_PASS_meridional_translation_speed**

All Best Track-related variables are calculated by interpolating the official IBTrACS Best Track storm data for track (latitude, longitude) and intensity (Vmax, Pmin) to each JPL QuikSCAT pass time. Interpolation is performed using a Piecewise Cubic Hermite Interpolating Polynomial (PCHIP). PCHIP is a shape-preserving cubic spline interpolant that, unlike a traditional cubic spline, does not permit local overshoot of the input data, resulting in a smoother interpolation devoid of potential numerical jumps that can arise in data whose first derivative does not change smoothly. Additionally, this interpolation technique produces cubic polynomial interpolants whose derivative can be readily calculated, yielding the interpolated local storm translation vector as well.

QuikSCAT Wind Data

Variables:
Wind radius (prefix **QS_WR**) – **QS_WR_wind_speed_thresholds**, **QS_WR_total_wind_speed, QS_WR_azimuthal_wind_speed, QS_WR_total_wind_speed_asymmetry_parameter, QS_WR_azimuthal_wind_speed_asymmetry_parameter, QS_WR_total_maximum_wind_speed_threshold, QS_WR_azimuthal_maximum_wind_speed_threshold, QS_WR_total_maximum_wind_speed, QS_WR_azimuthal_maximum_wind_speed, QS_WR_total_maximum_wind_speed_asymmetry_parameter, QS_WR_azimuthal_maximum_wind_speed_asymmetry_parameter**

Radial profile (prefix **QS_RP**) – **QS_RP_radius_coordinate**, **QS_RP_total_wind_speed, QS_RP_azimuthal_wind_speed, QS_RP_radial_wind_speed**, **QS_RP_asymmetry_parameter**

For each JPL QuikSCAT near-surface wind field file (netCDF format) available on the JPL FTP server (ftp://mwsci.jpl.nasa.gov), the following procedure is applied in order to calculate radial profiles of the total wind and its azimuthal and radial components:

1) *Isolate the storm flow field from the background flow field in which it is embedded*: Subtract from every wind vector an estimate of the near-surface background flow vector, which is assumed to vary slowly in space and thus is taken as a constant. Following Lin and Chavas (2012), the background flow vector is taken to equal the local Best Track translation vector (described above) reduced in magnitude by the factor .55 and rotated 20 degrees cyclonically (counterclockwise in the Northern Hemisphere). Note: the validity of the assumption of constant background flow is expected to decrease at increasingly large radii from the storm center.
2) *Define a local polar coordinate system relative to storm center*: At each gridpoint, calculate the great-circle distance to the storm center. This distance computation is based on the WGS-84 Earth ellipsoid model, which takes the major and minor axis lengths to be 6378.137 km and 6356.752 km, respectively. This quantity defines the gridpoint radius from storm center. Second, calculate the back azimuth, defined as the local directional heading from the gridpoint to the center. This azimuth corresponds to the inward radial

direction, with outward flow defined as positive. The azimuthal direction is by definition perpendicular to the radial direction, with cyclonic flow defined as positive.

3) *Decompose the flow field into its radial and azimuthal components*: Project the raw QuikSCAT wind vector at each gridpoint onto its local azimuthal and radial unit vectors.
4) *Calculate azimuthal-mean radial profiles*: Average all data within annuli of width Δr = 12.5 km (corresponding to the grid spacing of the source data) moving radially outwards from the center in increments of Δr/4 (i.e. 3.125 km). The assigned radius at each step is taken as the mean radius of the data within the given annulus.
5) *Extract relevant wind radii*: For a given radial profile, search for the first gridpoint beyond the radius of maximum wind whose wind speed drops below the desired wind speed. Linearly interpolate between this gridpoint and its inward neighbor to estimate the precise wind radius. If no such wind speed can be found, set to missing value flag.
6) *Interpolate radial profile to regular grid*: Interpolate the radial profile data to a uniform, gridded vector of radii, 3.125 to 1996.875 km in regular increments of Δr = 6.25 km. Interpolation performed using PCHIP (described earlier) with no extrapolation beyond regions containing continuous (i.e. 2 or more consecutive) valid data.

The variable **QS_RP_asymmetry_parameter** is a measure of the azimuthal asymmetry in data coverage used to calculate the radial wind profiles at each radial gridpoint. It takes values in the range [0,1], where 0 = perfect symmetry and 1 = perfect asymmetry. It is defined as the magnitude of the vector mean of all vectors from storm center to each grid point in a given radial bin, normalized by the mean distance to the gridpoint. In the case of perfect azimuthal symmetry in data coverage (i.e. data uniformly distributed at all azimuthal directions from storm center), the value equals zero; in the case of a single datapoint at a single azimuth, the value equals one. Higher asymmetry is indicative of higher uncertainty in the true azimuthal-mean value. See below for further discussion of uncertainty. This quantity is interpolated to each available wind radius and radius of maximum wind for both the total and azimuthal wind (e.g. **QS_WR_total_wind_speed_asymmetry_parameter**) to provide a local estimate of the data coverage asymmetry at these radii.

For more practical information on how to use the wind radii included herein, see the section below titled "Wind Radii: Filtering the Data".

References:

Lin, Ning, and Daniel Chavas. "On hurricane parametric wind and applications in storm surge modeling." *Journal of Geophysical Research: Atmospheres (1984–2012)* 117.D9 (2012).

QuikSCAT Rain Rate and SSM/I Cloud Data

Variables: **QS_RP_rainrate**, **QS_RP_asymmetry_parameter_rainrate, QS_RP_cloudssmi, QS_RP_asymmetry_parameter_cloud**

In addition to wind vector data, the JPL QuikSCAT database also includes QuikSCAT radiometric measurements of a quantity proportional to rain rate (units: proportional to mm/hr) as well as collocated SSM/I cloud liquid data (units: g/kg). Radial profiles of these quantities are thus calculated in the same manner as detailed above for the wind variables.

The rain rate quantity is estimated from QuikSCAT radiometric brightness temperature measurements produced by Dr. Linwood Jones, University of Central Florida (Ahmad et al. 2005). The cloud liquid data is taken from collocated Special Sensor Microwave Imager (SSM/I) passive microwave radiometer data as provided in the JPL database.

For rain rate, data coverage is identical to that of the wind vector data, with one exception: in the vicinity of the coastline, rain rates equal zero artificially. This is a known issue in the JPL dataset that has yet to be addressed. For the construction of the current version of the QSCAT-R dataset, we first remove all rain rate data within 100km of the coast to crudely account for this problem. Once the JPL dataset is updated to properly account for this issue, the QSCAT-R dataset will be updated accordingly in a future release. For SSM/I cloud data, coverage depends on proximity of the SSM/I swath to that of QuikSCAT, and thus varies on a case-by-case basis. To account for these variations in data coverage, data coverage asymmetry parameters are also included for these variables (**QS_RP_asymmetry_parameter_rainrate, QS_RP_asymmetry_parameter_cloud**) and are calculated in an identical fashion to that for the wind vector data.

Uncertainties

It is important to acknowledge potential uncertainties in the radial profile data. Below are documented four key uncertainties, though this may not be an exhaustive list:

1) Data coverage asymmetry

Azimuthally-periodic asymmetries are a common occurrence in the wind field of TCs. In the case of perfectly symmetric data coverage, such asymmetries would be averaged out, lending high confidence in the estimate of the azimuthal-mean wind speed. In contrast, in the case of azimuthally-asymmetric data coverage, such asymmetries may not be fully averaged out, thereby biasing the calculated azimuthal-average away from its true value. A simple example: for the purposes of calculating an azimuthal mean, in most cases one would prefer only four measurements, each 90 degrees apart in azimuth, to 1000 measurements all within a limited azimuthal band. The degree of azimuthal symmetry in data coverage is highly variable throughout the dataset and is modulated predominantly by two factors: 1) the location of the QuikSCAT swath relative to the storm center, and 2) the existence and extent of land in the vicinity of the storm, over which QuikSCAT cannot make a measurement.

For the wind data, the variable **QS_RP_asymmetry_parameter** is provided as a quantitative measure of this type of uncertainty, as well as local values at available wind radii (**QS_WR_total_wind_speed_asymmetry_parameter**). Identical variables are provided for rain rate and SSM/I cloud data (**QS_RP_asymmetry_parameter_rainrate, QS_RP_asymmetry_parameter**_cloud). See variable description provided above for details.

2) Azimuthal-radial decomposition at small radii

The azimuthal-radial decomposition is much less certain in the inner core of the storm due to the combined uncertainties in i) wind vector direction at high wind speeds and in rainy conditions, and ii) storm center location; for full details, see Hoffman and Leidner (2005). Moreover, errors in storm-center location may result in wind vectors at small radii being placed on the wrong side of the storm. Given this behavior and the sensitivity of the azimuthal-radial partitioning to small changes in the TC center location at small radii, the decomposed flow data is not recommended for use in the vicinity of the radius of maximum wind.

3) Assumption of constant background flow at large radii

Due to the slow spatial variation of tropical circulations, the assumption of constant background flow is expected to be locally valid. However, azimuthal-mean quantities are calculated using data at increasingly distant gridpoints across the storm as one moves radially outwards from storm center, thus increasing uncertainty in the radial profile calculation at large radii. The validity of this assumption will be case-specific and will depend on the length scale over which the actual background flow varies at any given point in space and time. Experience dictates that this assumption is reasonably valid for radii less than approximately 1000 km, though this has not been quantitatively tested, and thus caution is warranted in interpreting data at large radii.

Furthermore, the estimation of surface background flow employed here is relatively crude and whose functional relationship is assumed to invariant across all storms. This neglects real variability across space and time, particularly in the context of extra-tropical transition where baroclinic effects may substantially alter the relationship between translation speed and background surface flow.

4) QuikSCAT wind speed uncertainty above 40 ms^{-1}

As noted above, the QuikSCAT JPL wind vector product has been optimized to be accurate for wind speeds up to 40 ms^{-1} and in all weather conditions. At higher wind speeds, accuracy decreases (see Stiles et al. 2013), and it should be noted that radial wind profile wind speeds below 40 ms^{-1} may be calculated from data that are both above and below this threshold. Furthermore, though now valid in all weather conditions, heavy rain will necessarily reduce the effective horizontal resolution due to the neural network algorithm applied.

For complete information on uncertainties regarding the raw QuikSCAT data and Best Track data, please consult the relevant references discussed above.

For further information on Best Track data uncertainty, the reader is referred to the following references:

McAdie, C. J., C.W. Landsea, C. J. Neumann, J. E. David, E. S. Blake, and G. R. Hammer, 2009: Tropical cyclones of the North Atlantic, 1851–2006 (6th ed.). Historical Climatology Series 6-2. [Available from the National Climatic Data Center, 151 Patton

Avenue, Room 120, Asheville, NC 28801-5001. Also available online at: http://www.nhc.noaa.gov/abouttrackbooks.shtml].

Landsea, Christopher W., and James L. Franklin. "Atlantic Hurricane Database Uncertainty and Presentation of a New Database Format." *Monthly Weather Review* 141.10 (2013).

Torn, Ryan D., and Chris Snyder. "Uncertainty of Tropical Cyclone Best-Track Information." *Weather & Forecasting* 27.3 (2012).

Wind Radii: Filtering the Data

The wind radii values included in this dataset are unfiltered to avoid unnecessary reduction of information. However, under certain circumstances the wind radius may therefore be subject to very large uncertainty or may even be completely in error. For this reason the user is strongly encouraged to compare a given wind radius directly with the corresponding radial profile provided herein to determine whether the wind radius is satisfactory for the intended purpose.

Nonetheless, the following filters may be useful for eliminating high-uncertainty cases, though in the process may eliminate valid cases as well:

1) Local data asymmetry (e.g. **QS_WR_total_wind_speed_asymmetry_parameter**): high values of the data asymmetry parameter imply low azimuthal data coverage. Retaining only cases with sufficiently low values (e.g. < .5) will increase the likelihood of valid data.
2) Best Track storm intensity (**QS_PASS_vmax**): weak storms are likely to have a less symmetric wind field, which may result in variations of wind with radius that deviates from expectations.
3) Peak wind speed QuikSCAT radial profile (e.g. **QS_WR_total_maximum_wind_speed**): If the QuikSCAT radial profile includes wind speeds significantly higher than a given wind radius, this increases confidence in the wind profile as a whole and, in turn, in the correct estimation of the wind radius value.

Errors and Questions

If you find any errors or have any questions regarding the data or methodology, please kindly send an email to Dan: drchavas@gmail.com .

Acknowledgements

The authors gratefully thank Bryan Stiles and Svetla Hristova-Veleva of the NASA Jet Propulsion Laboratory (JPL) for all of their hard work in creating the 2-D QuikSCAT-based tropical cyclone wind field products used as the basis for this dataset, as well as for their assistance in navigating data access and understanding the origins and limitations of the data. Additionally, the authors thank Daniel Stern of the National Center for Atmospheric Research (NCAR) for his timely review of this document. NCAR is sponsored by the National Science Foundation. This work was supported by grants from the Risk Prediction Initiative of the Bermuda Institute of Ocean Sciences and the National Science Foundation (NSF, grant number AGS-1331362). The views expressed herein do not necessarily reflect the views of any of these organizations.