Physical Oceanography Distributed Active Archive Center (PO.DAAC)

RapidScat Level 2B NetCDF

Guide Document

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Jet Propulsion Laboratory, California Institute of Technology

Pasadena, California

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1. Abstract:

This ocean surface wind vector dataset is provided as a service to the oceanographic and meteorological research communities on behalf of the NASA/JPL RapidScat Science Data Systems (SDS) Team in collaboration with the NASA International Ocean Vector Winds Science Team (IOVWST). This document details the RapidScat Level 2B (L2B) dataset which provides nominal 12.5 km (pixel spacing) swath bins of ocean surface wind vector retrievals with approximately 90% global coverage between 56° S and 56° N latitude within 48 hours. This is the initial release of the User's Guide describing the initial release V1.0 of the data and V1.1 which has improved performance for high winds. Improvements to the geophysical model function (GMF) for wind retrieval and if necessary refinements to calibration due to comparison with other scatterometers are planned for future versions. This latest processing version is consistently calibrated with the QuikSCAT Version 3 L2B datasets. This RapidScat L2B dataset incorporates most of the QuikSCAT Version 3 algorithm updates, product development, and calibration/validation information, which is described in further detail by Fore et al. (2013). Development and distribution of this dataset is made possible through funding provided by NASA.

2. Acknowledgements:

NOTE: Please refer all questions concerning this dataset to PO.DAAC User Services: podaac@podaac.jpl.nasa.gov.

The research described within this document was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. The following people have contributed to the procurement of this dataset and user guide documentation:

Principal Investigator:
Dr. Ernesto Rodriguez[1]

Co-Investigators:
Bryan Stiles[1], Frank Wentz[2], Thomas Werne[1], Alexander Fore[1], Philip Callahan[1], Scott Dunbar[1], Brent Williams[1], Alexandra Chau[1], and Sermsak Jaruwatanadilok[1]

User Guide Authors:
David Moroni[1]
Bryan Stiles[1]
Douglas Tyler[1]
Alex Fore[1]

[1]Jet Propulsion Laboratory, California Institute of Technology
[2]Remote Sensing Systems

3. Mission Description:

The International Space Station (ISS) RapidScat (hereafter, ISS-RapidScat) mission is a time-series continuation mission to fill the gap created by the loss of data from the NASA QuikSCAT mission, which due to a mechanical failure officially stopped providing a continuous data record of ocean vector winds beyond 22 November 2009. ISS-RapidScat was launched from Cape Canaveral, Florida on a Space-X Dragon on 15 September 2014. ISS-RapidScat is expected to remain operational through a minimum of two years from the initial date of launch, with possible extension of mission life through the Senior Review process until it is deemed no longer able to provide scientifically useful data or is superceded due to other demands for space on the international space station.

The legacy of the RapidScat instrument is from recycled spare parts of the SeaWinds instrument, which was previously flown on QuikSCAT and ADEOS-II. RapidScat is a specialized microwave radar that measures near-surface wind speed and direction under all weather and cloud conditions over Earth's oceans, both night and day. Scatterometer wind data, combined with measurements from various scientific disciplines, will help to understand mechanisms of global climatic change and weather. These measurements will help to determine atmospheric forcing, ocean response and air-sea interaction mechanisms on various spatial and temporal scales. Wind stress is the single largest source of momentum to the upper ocean, driving oceanic motions on scales ranging from surface waves to basin-wide current systems. Winds over the ocean modulate air-sea fluxes of heat, moisture, gases and particulates, regulating the crucial coupling between atmosphere and ocean that establishes and maintains global and regional climate. Measurements of surface wind velocity can be assimilated into regional and global numerical weather and wave prediction models, improving our ability to predict future weather.

ISS flies at an altitude approximately half that of QuikSCAT, which allows RapidScat to retrieve wind vectors in an asynchronous orbit with respect to the sun. This daytime/nighttime asynchronicity enables RapidScat to retrieve winds at the same location at variable times of the day which can provide two distinct advantages over a sun-synchronous platform: 1) more precise temporal co-location between multiple remote sensing spacecraft and 2) observation of diurnal processes.

As the only remote sensing system able to provide accurate, frequent, high-resolution measurements of ocean surface wind speed and direction under both clear sky and cloudy conditions, day and night, scatterometers have played an increasingly important role in oceanographic, meteorological and climatic studies over the past several decades. Scatterometers use an indirect technique to measure wind velocity over the ocean, since the atmospheric motions themselves do not substantially affect the radiation emitted and received by the radar. These instruments transmit microwave pulses and receive backscattered power from the ocean surface. Changes in wind velocity cause changes in ocean surface roughness, modifying the radar cross-section of the ocean and the magnitude of the backscattered power. Scatterometers measure this backscattered power, allowing estimation of the normalized radar cross-section (σ_o) of the sea surface. Backscatter cross section varies with both wind speed and direction when measured at moderate incidence angles. Multiple, collocated, nearly simultaneous σ_o measurements acquired from several directions can thus be used to solve simultaneously for wind speed and direction.

The first spaceborne scatterometer flew as part of the Skylab missions in 1973 and 1974, demonstrating that spaceborne scatterometers were indeed feasible. The Seasat-A Satellite Scatterometer (SASS) operated from June to October 1978 and proved that accurate wind velocity measurements could be made from space. The SASS cross section measurements have been used to significantly refine the empirical model relating backscatter to wind velocity, and the SASS data have been applied to a variety of oceanographic and meteorological studies. As a much improved extension of the European Space Agency's Earth Remote Sensing (ERS) scatterometer data record (ERS-1/2), the Advanced Scatterometer (ASCAT) provided by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) flown on MetOp-A/B has extended the previous single-swath scatterometer into a dual-swath instrument operating at C-band and providing an extended global time series of ocean surface wind vectors from March 2007 through present. NSCAT was launched on ADEOS-1 (Midori) in August 1996 and returned nearly 10 months of dual-swath, 25-km resolution Ku-band backscatter and wind data until the demise of the spacecraft in June 1997. QuikSCAT was launched by NASA on June 20, 1999 and provided calibrated ocean surface vector winds until November 22, 2009 when it ceased nominal operations due to a failure of its antenna spin mechanism. QuikSCAT continues to produce calibrated backscatter data albeit on a narrow 25-km wide swath that is useful for calibrating other scatterometers including RapidScat. The SeaWinds on Midori-II mission, which employed a clone of the QuikSCAT instrument, operated from December 14, 2002 until October 2003 allowing tandem mission with 4 local time-of-day Ku-band measurements during its lifetime. A similar scatterometer (OSCAT) onboard OceanSAT-2 was flown by the Indian Space Research Organization from September 23,2009 to February 20, 2014. A wind vector data product consistent with QuikSCAT and RapidScat was produced for OSCAT by JPL and is archived by PO.DAAC.

3.1 Mission Requirements

The temporal scales of important motions in the atmosphere and the ocean range from seconds to decades, and spatial scales range from meters to tens of thousands of kilometers. Given the wide range of geophysical studies requiring surface wind velocity data, construction of a unified, consistent, achievable set of requirements for a satellite instrument is difficult. Following the successful flight of the Seasat scatterometer (SASS) in 1978, NASA established the interdisciplinary Satellite Surface Stress Working Group to define the scientific requirements for the next spaceborne NASA scatterometer system. As understanding of both science issues and scatterometer capabilities grew during the 1980's, the Working Group report evolved into specific mission requirements. In short, the system must measure winds between 3 and 30 m/s with an accuracy better than (the greater of) 2 m/s or 10% in speed and 20° in direction with a spatial resolution of 50 km;

virtually the entire ocean surface must be covered at least once every two days; geophysically useful products must be produced within days after data are acquired; and the instrument must be designed to acquire data for at least three years in order to allow investigation of annual and inter-annual variability. A summary of the ISS-RapidScat technical requirements is given in Table 1.

Quantity	Requirement	Applicable Range
Wind speed	2 m/s (rms)	3-20 m/s
	10%	20-30 m/s
Wind direction	20^o (rms) selected ambiguity	3-30 m/s
Spatial resolution	25 km	σ_o cells
	25 km	Wind vector cells
Location accuracy	25 km (rms)	Absolute
	10 km (rms)	Relative
Coverage	90% daily coverage between 56 degrees N and S latitude	Global
Mission duration	24 months	24-36 Months

Table 1: ISS-RapidScat Technical Mission Requirements

3.2 Satellite Description

The NASA ISS-RapidScat instrument is mounted on the international space station. Table 2 outlines the nominal orbit parameters for ISS.

Orbital Period (range)	91 to 93 minutes (16 orbits/day)
Altitude above Equator (range)	370-460 km
Inclination	51.65^o

Table 2: ISS Nominal Orbit Parameters

4. Sensor Overview:

The RapidScat instrument is an active microwave radar designed to measure electromagnetic backscatter from wind-roughened ocean surface. RapidScat uses a rotating dish antenna with two spot beams that conically sweep producing a circular pattern on the Earth's surface. The antenna radiates microwave pulses at a frequency of 13.4 GHz (Ku-band) across broad regions on Earth's surface. The instrument collects data over ocean, land, and ice in a continuous, 1000-kilometer-wide swath centered on the nadir subtrack, making approximately 1.1 million ocean surface wind measurements and covering 90% of Earth's ocean surface (between 56° N and 56° S latitude) every 2 days. A pencil-beam scatterometer has several key advantages over a fan-beam scatterometer: it has a higher signal-to-noise ratio, is smaller in size, and provides superior coverage.

4.1 Principles of Operation

Spaceborne scatterometers transmit microwave pulses to the ocean surface and measure the backscattered power received at the instrument. Since atmospheric motions themselves do not substantially affect the radiation emitted and received by the radar, scatterometers use an indirect technique to measure wind velocity over the ocean. Wind stress over the ocean generates ripples and small waves, which roughen the sea surface. These waves modify the σ_o of the ocean surface and hence the magnitude of backscattered power. In order to extract wind velocity from these measurements, one must understand the relationship between σ_o and near-surface winds (i.e., the GMF).

The RapidScat scatterometer design, which is also shared by QuikSCAT and SeaWinds on Midori-II, is a significant departure from the fan-beam scatterometers flown on previous missions (Seasat SASS and NSCAT) and the current ASCAT. RapidScat employs a single 1-meter parabolic antenna dish with twin-offset feeds for vertical and horizontal polarization. The antenna spins at a rate of 18 rpm, scanning two pencil-beam footprint paths at nominal incidence angles of 49° (H-pol, inner beam) and 56° (V-pol, outer beam). The transmitted radar pulse is modulated, or "chirped", and the received pulse (after Doppler compensation) is passed through an FFT stage to provide sub-footprint range resolution. The range resolution may be commanded between 2 km and 10 km, with the nominal value set at about 6 km. The nominal pulse repetition frequency is 166.37 Hz. Each telemetry frame contains data for 100 pulses. Signal and noise measurements are returned in the telemetry for each of the 12 sub-footprint "slices." Ground processing locates the pulse "egg" and "slice" centroids on the Earth's surface. The σ_o value is then computed for both the "egg" and the best 8 of the 12 "slices" (based on location within the antenna gain pattern).

RapidScat generates an internal calibration pulse and associated load pulse every scan of the antenna. In ground processing, the load pulses are averaged over a 20-minute window, and the calibration pulses over a 10-pulse (approximately 18-second) window, to provide current instrument gain calibration needed to convert telemetry data numbers into power measurements for the σ_o calculation.

5. Processing Methodology:

Instrument power measurements are calibrated and converted to normalized radar cross section (σ_o) to produce the time-ordered Level 1B (L1B) product. The σ_o measurements are then grouped into an along-track, cross-track grid of "wind vector cells" (WVC) for wind retrieval, which is known hereafter as Level 2A (L2A). A WVC typically contains several measurements looking both forward and backward from both the inner and outer beams. Slice measurements are grouped into both 25 km and 12.5 km WVC resolution. The tradeoff is between resolution and noise. Data products indicate the resolution. The data described here are L2B 12.5 km WVC resolution netCDF data files. The L1B and L2A data products remain in their native HDF-4 format.

Wind retrieval processing is performed in three steps. First, a point-wise maximum likelihood estimate of wind speed and wind direction is computed resulting in multiple ambiguous solutions (typically two to four). Next, a median filter is used to select the best ambiguity. Finally, Directional Interval Retrieval (DIR) (Stiles et al. 2002) processing is performed, which uses the directional spread of the objective function and allows the retrieved wind direction to vary within a region of high likelihood about the selected ambiguity.

Version 3 products have several improvements over the previous JPL processing of the QuikSCAT L2B winds. Version 3 processing begins with the same L1B (time-ordered backscatter) data as used in the previous processing. The first set of changes was with respect to measurement binning, which was done in order to decrease noise and reduce gaps in the 12.5 km L2B wind retrievals. The next step was an improved geophysical model function (GMF) to model the effect of wind on backscatter. An important effect in Ku-band derived winds is rain, so a neural network approach was implemented to correct rain contaminated winds speeds[Stiles and Dunbar, 2010). Finally, cross-track dependent wind speed biases were estimated and removed from the wind retrievals.

More details of the Version 3 processing methodology are found in Fore et al. (2013): ftp://podaac.jpl.nasa.gov/allData/quikscat/L2B12/docs/fore_et_al_ieee_2013.pdf. The details regarding the processing lifecycle from telemetry to L2B may be found in the "QuikSCAT Science Data Product User's Manual" (Version 3.0, 2006): ftp://podaac.jpl.nasa.gov/allData/quikscat/L2B/v2/docs/QSUG_v3.pdf

RapidScat Version 1.0 data is processed similarly to QuikSCAT Version 3. Version 1.1 has an additional improvement to the neural network wind speed correction in rain that allows for more accurate corrected speeds in storms and other areas of high wind (>20 m/s). To achieve this performance a hybrid technique incorporates the two speed corrections described in [Stiles and Dunbar, 2010 and Stiles et al, 2014] whenever rain contamination is detected. Both the corrected speeds and the DIRTH speeds without rain correction are included in the data product.

6. Calibration and Validation:

The RapidScat L2B winds have been compared to the WindSAT all-weather wind product [Meissner et al, 2009], ECMWF, and buoy winds in order to assess accuracy. Version 1.1 was found to be more accurate than Version 1 when compared with WindSAT wind data sets. The only significant difference between the two occurred at high winds where ECMWF and buoy wind speeds are unreliable, and poorly sampled, respectively. The change in the speed correction method resulted in more than 0.1 m/s changes in corrected speed from V1.0 to V1.1 only 0.5% of the time. (A close examination of the two data sets will find more frequent differences due to improvements in backscatter data quality checking unrelated to wind retrieval.) In rain-free conditions, RMS speed error with respect to ECMWF is 1.5 m/s; RMS direction error is 18°. See Figure 1 below.

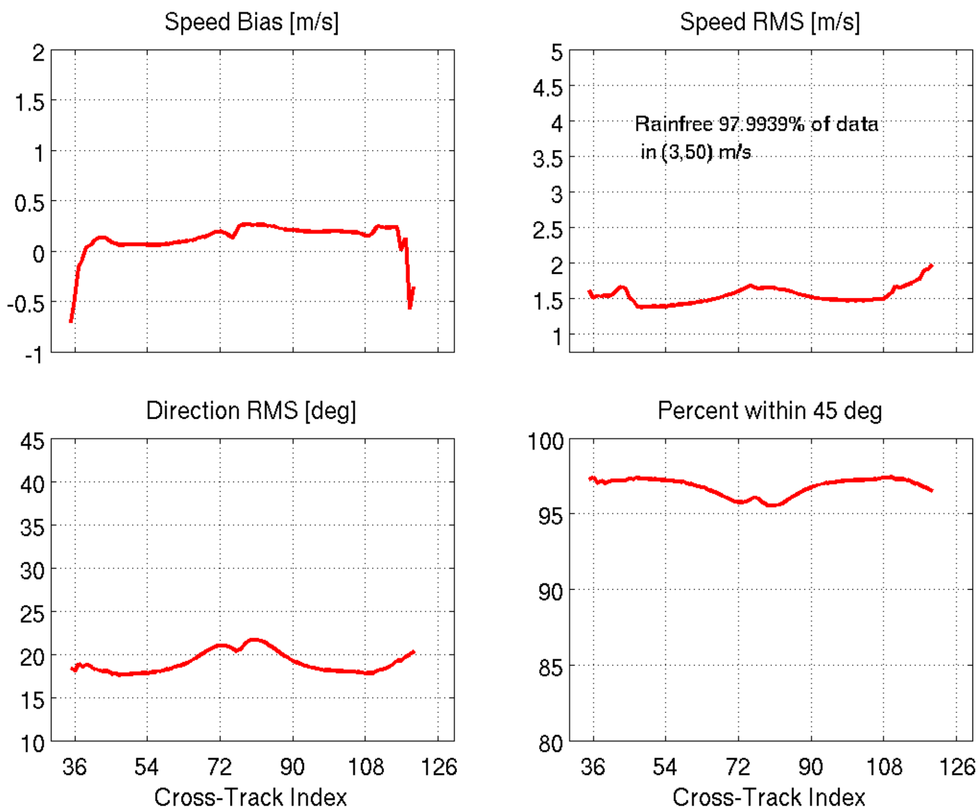

Figure 1: Bias and RMS error w.r.t to ECMWF for Version 1.1 in rain-free conditions. The upper two panels and Speed Bias and RMS respectively. For rain-free conditions the performance of the V1.0, Version 1.1, and DIRTH (uncorrected) retrieved speeds do not differ significantly. The bottom left panel depicts RMS direction error. The bottom right panel depicts the percentage of time the retrieved (DIRTH) direction is within 45° of ECMWF. The x-axis units are cross track bins 12.5-km in width.

In rainy conditions, DIRTH directions and speeds do not compare well with ECMWF. Figure 2 depicts the performance w.r.t. ECMWF for data flagged as rainy. Speed biases are typically 6 m/s and RMS speed differences are 8 m/s. Direction RMS in rain is 40°.

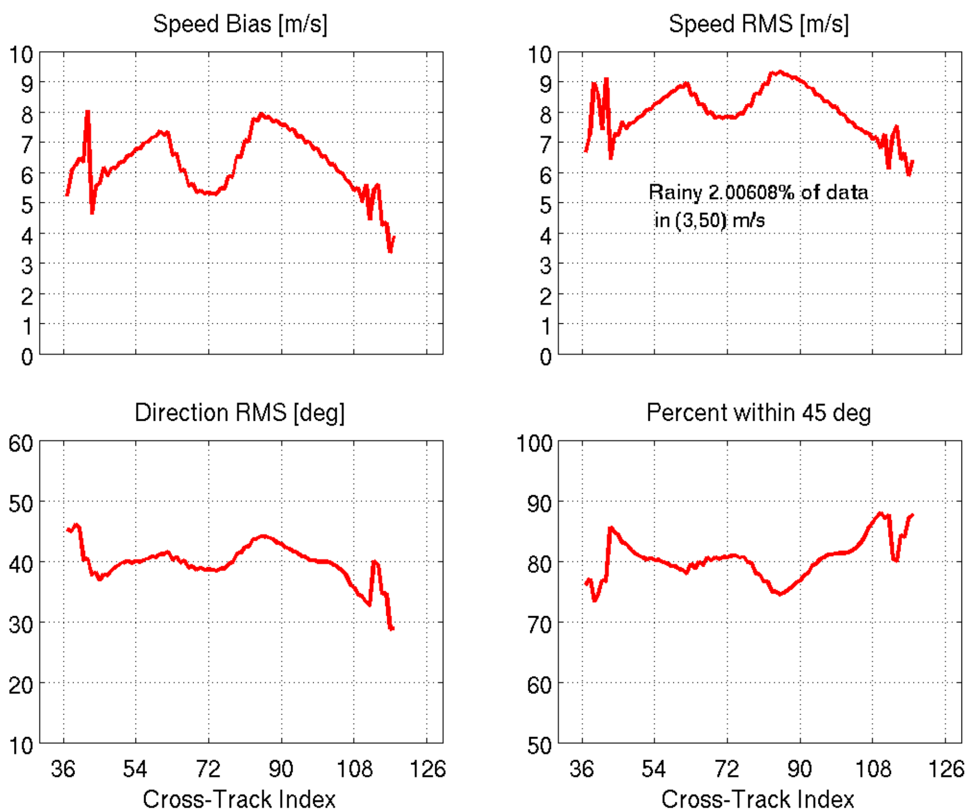

Figure 2: Performance of uncorrected (DIRTH) RapidScat winds for rainy data.

Because of the neural network speed correction, the Version 1.1 corrected speeds compare much better to ECMWF. Speed biases are less than 2 m/s and RMS are 4 m/s for the portion of the swath where correction is possible. See Figure 3.

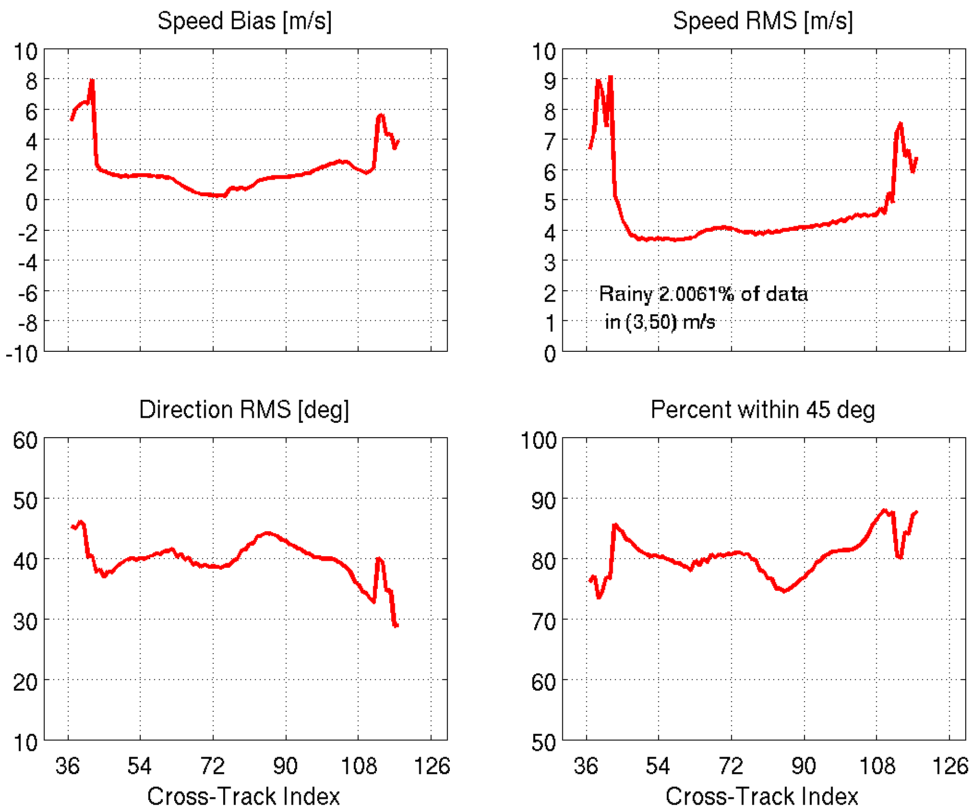

Figure 3: Performance of Version 1.1 (speed corrected) RapidScat winds vs. ECMWF. The performance is similar to Version 1.0, because the conditions where the two corrections differ occur infrequently. Directions are not corrected for rain and thus are identical to the DIRTH directions. Speeds are substantially improved (compare to Figure 2) except in the outer swath where corrections cannot be performed. The speed correction utilizes inner beam HH and outer beam VV backscatter measurements and cannot be employed at the extreme edge of the swath where only VV measurements are acquired.

To compare RapidSCAT Version 1.0 and Version 1.1 winds in the high wind, rainy cases where version 1.1 is designed to offer improvement, we use the WindSAT polarimetric radiometer winds [Meissner, 2009] as a yardstick. Figure 4 depicts the biases and error 1-standard deviation error bars between RapidScat corrected wind speeds and WindSAT speeds for the 99.5% of wind vector cells where version 1.0 and Version 1.1 do not signicantly differ. Figure 5 depicts the comparison for both versions when they do differ,

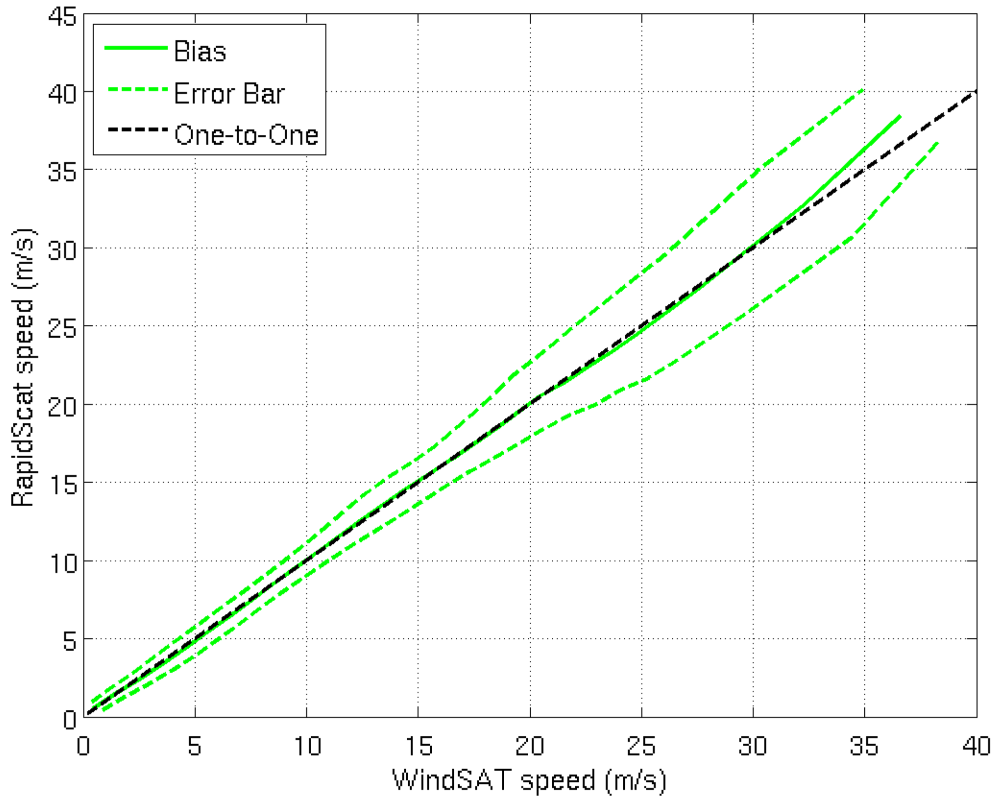

Figure 4: Comparison between RapidScat and WindSAT speeds where version 1.0 and version 1.1 speeds do not differ. The data was binned according to the mean of the RapidScat and WindSAT speeds and then the bias and standard deviation was computed for each bin to construct the plot.

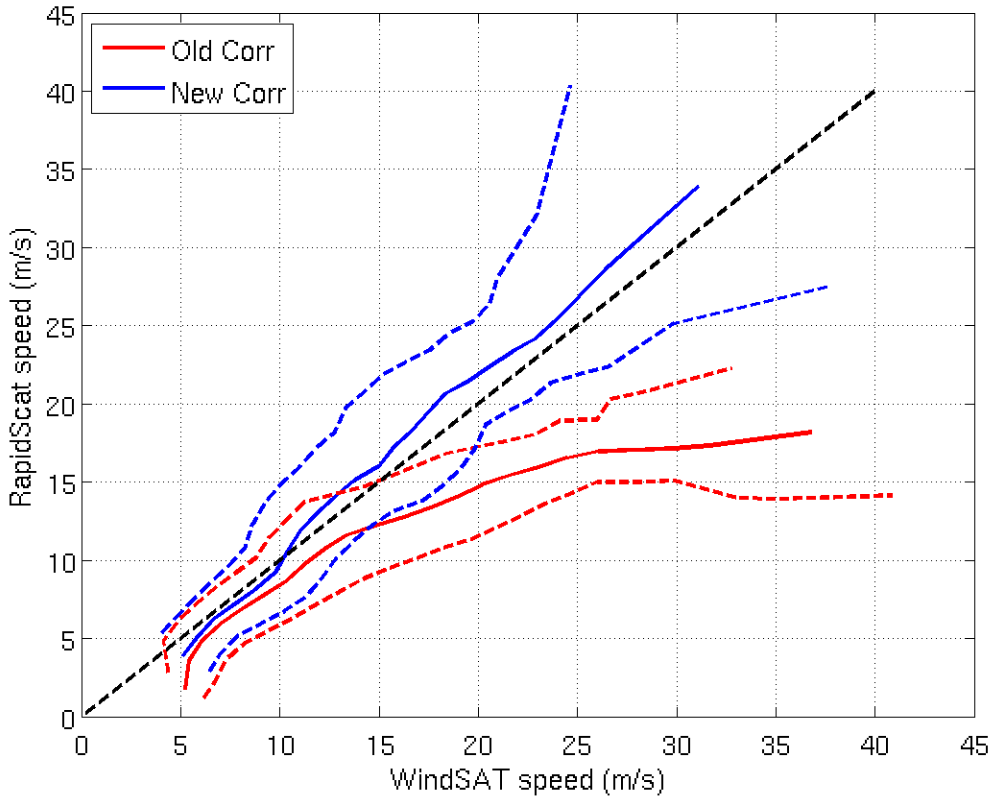

Figure 5: Comparison between RapidScat and WindSAT speeds where version 1.0 and version 1.1 speeds do differ. The data was binned according to the mean of the RapidScat and WindSAT speeds and then the bias and standard deviation was computed for each bin to construct the plot. Blue lines are Version 1.1 bias and error bars. Red lines are Version 1.0 bias and error bars.

7. Dataset Description:

This data set is being distributed in netCDF version 4 classic (i.e., compatible with netCDF Version 3) format, adhering to CF v1.5 conventions. Each file is unique to a particular calendar day of a year and consists of one complete orbital revolution (assuming no data gaps).

7.1 File Naming Convention

The file naming convention is rs_l2b_vN.N_RRRRR_YYYYMMDDhhmm.nc, where:

rs = RapidScat, which is the instrument/platform source of the dataset

l2b = the processing level of the dataset vN.N = the dataset version identifier of the data file, containing up to 2 numerical digits reserved by ‘N.N’

RRRRR = the 5-digit starting orbital revolution number

YYYY = the 4-digit calendar year of the file creation time

MM = the 2-digit calendar month of year of file creation (e.g., 09 = September)

DD = the 2-digit calendar day of month of file creation

hh = the 2-digit hour of the file creation time

mm = the 2-digit minute of the file creation time

.nc = the file extension indicating the usage of netCDF data formatting

The date and time represented by the file name is with respect to GMT (UTC). To retrieve the actual start and stop times of data observations for each file, as well as the equatorial crossing times, one must refer to the netCDF global attributes.

7.2 Variable Types

Name	Along Track Cells	Cross Track Cells	Data Type	Missing Value	Description
time	3248	N/A	double	N/A	Defines the mean reference time of all WVC measurements along a given WVC row referenced by the number of seconds since 00Z on 1 January 1999.
lat	3248	152	float	N/A	The latitude value at WVC.
lon	3248	152	float	N/A	The longitude value at WVC.

retrieved_wind_speed	3248	152	float	-9999.f	Equivalent neutral wind speed at reference height of 10 m. Corrected using neural network when rain is detected.
retrieved_wind_direction	3248	152	float	-9999.f	Equivalent neutral wind direction at reference height of 10 m.
rain_impact	3248	152	float	-9999.f	Impact of rain upon wind vector retrieval.
flags	3248	152	short	32767s	WVC bit-wise quality flags.
eflags	3248	152	short	32767s	Extended WVC bit-wise quality flags
nudge_wind_speed	3248	152	float	-9999.f	NCEP Model wind speed.
nudge_wind_direction	3248	152	float	-9999.f	NCEP Model wind direction.
retrieved_wind_speed_uncorrected	3248	152	float	-9999.f	Wind speed without rain correction.
cross_track_wind_speed_bias	3248	152	float	-9999.f	Relative wind speed bias with respect to the “sweet spot”. Zeroed out for

					now. Currently no cross-track speed correction is applied
atmospheric_speed_bias	3248	152	float	-9999.f	Atmospheric wind speed bias. Speed bias removed by rain correction algorithm.
num_ambiguities	3248	152	byte	0b	Number of ambiguous wind directions found in point-wise wind retrieval prior to spatial filtering.
ambiguity_speed	3248	152	4 floats	0	3248 by 152 by 4 array of speeds for each ambiguity in the point-wise wind retrieval step.
ambiguity_direction	3248	152	4 floats	0	3248 by 152 by 4 array of directions for each ambiguity in the point-wise wind retrieval step.
ambiguity_obj	3248	152	4 floats	0	3248 by 152 by 4 array of objective function values for each ambiguity in the point-wise wind retrieval step.

number_in_fore	3248	152	short	0	Number of valid measurements from the fore look of the inner HH beam found in a wind vector cell
number_in_aft	3248	152	short	0	Number of valid measurements from the aft look of the inner HH beam found in a wind vector cell
number_out_fore	3248	152	short	0	Number of valid measurements from the fore look of the outer VV beam found in a wind vector cell
number_out_aft	3248	152	short	0	Number of valid measurements from the aft look of the outer VV beam found in a wind vector cell

Table 3. Dataset Variable Description

7.3 Global Attributes

Attribute Names	Examples
title	Rapidscat Level 2B Ocean Wind Vectors in 12.5km Slice Composites
source	Rapidscat Scatterometer
comment	Rapidscat Level 1B Data Processed to Winds Using QuikSCAT v3 Algorithms

history	2015-106T16:22:49+0000 rscatsa /u/patience-r0/rscatsa/rscat-ops-sds-v0/bin/l2b_to_netcdf --l2bhdf /u/patience-r0/rscatsa/rscat-ops-sds-v0/L2B/12/data/RS_S2B01546.20151000403.CP12 --l1bhdf /u/patience-r0/rscatsa/rscat-ops-sds-v0/L1B/data/RS_S1B01546.20151000359 --nc l2b.nc --l2b l2b_flagged_S3.dat --l2b_ambig l2b.dat\0122015-106T16:22:50+0000 rscatsa /u/patience-r0/rscatsa/rscat-ops-sds-v0/bin/rs_update_nc.py --nc l2b.nc --rdf RS01546.rdf\012
Conventions	CF-1.6
data_format_type	NetCDF Classic
processing_level	L2B
date_created	2015-106T16:22:49
LongName	Rapidscat Level 2B Ocean Wind Vectors in 12.5km Slice Composites
ShortName	RSCAT_LEVEL_2B_OWV_COMP_12_V1
GranulePointer	rs_l2b_v1.1_01546_201504160922.nc
l2b_algorithm_descriptor	Uses NSCAT 2014 GMF developed by Remote Sensing Systems.\012Applies median filter technique for ambiguity removal.\012Ambiguity removal median filter is based on wind vectors over a 7 by 7\012wind vector cell window. Applies no median filter weights. Enhances\012the direction of the selected ambiguity based on the range of\012directions which exceed a specified probability threshold.\012Applies multi-pass median filter technique to reduce the effects of\012rain flagged cells on ambiguity selection.\012Applies Neural Network Rain Correction Version 2 which is applicable to\012high winds.
cross_track_resolution	12.5
along_track_resolution	12.5
zero_index	76
version_id	1.1

NetCDF_version_id	4.3.2 of Jan 14 2015 09:50:47 $
references	null
InstrumentShortName	RapidScat
producer_agency	NASA
institution	JPL
PlatformType	spacecraft
PlatformLongName	International Space Station
PlatformShortName	ISS
project	RapidScat
QAPercentOutOfBoundsData	0
QAPercentMissingData	52
sis_id	686-644-3/2006-09-26
OrbitParametersPointer	RS_SEPHG_01546_20150010032.20150011032
OperationMode	Wind Observation
StartOrbitNumber	1545
StopOrbitNumber	1546
EquatorCrossingLongitude	82.6026001
EquatorCrossingTime	01:00:58.530
EquatorCrossingDate	2015-001
rev_orbit_period	5560.19678
orbit_inclination	51.6595001
rev_orbit_semimajor_axis	6792780.00
rev_orbit_eccentricity	0.000686605810

rev_number	1546
RangeBeginningDate	2015-001
RangeEndingDate	2015-001
RangeBeginningTime	00:37:46.748
RangeEndingTime	02:10:26.945
ephemeris_type	GPS
sigma0_granularity	slice composites
median_filter_method	Wind vector median
sigma0_attenuation_method	Attenuation Map
nudging_method	NWP Weather Map probability threshold nudging.
ParameterName	wind_speed_selection
InputPointer	RS_S2A01546.20151000402.CP12
ancillary_data_descriptors	QS_PC2B0006.CP12\012QS_MC2B0001\012SNWP1201500100\012RS_MODL_NSCAT_2014_EXTENDED\012GLOB0003\012QS_CN2B1130.CP12\012QS_MRCL1130.CP12\012QS_EMOF0001.CP12\012QS_OBTB0001\012LMAP1111\012NCEP_SEAICE_2015001\012RS_MODL_NSCAT_2014-V3proc-extended.dat\012QS_KPRP0002_SimFormat.dat\012kpm_fixed.dat\012ATTN0001\012SNWP1201500100\012liqnet1_June_22_2010.net\012spdnet1_June_22_2010.net\012spdnet2_June_22_2010.net\012rainflagnet_June_22_2010.net\012rs-ann-hist-match.mat\012rs-ann-stage1.mat\012rs-ann-stage2.mat

Table 4. Dataset Global Attributes Description

7.4 Grid Description

The data is binned in a swath grid pattern at 12.5 km pixel resolution. There are 152 WVCs in the across-track direction and 3248 WVC rows in the along-track direction. The very first WVC row is defined by the beginning of the ascending node with respect to the nadir position of the spacecraft. Full orbital coverage of the earth's circumference requires 3248 rows at 12.5 km pixel resolution (i.e., a single data file with no measurement gaps).

RapidScat's swath footprint extends approximately 500 km on either side of the satellite nadir track, providing a full swath width of 1000 km. However, to maintain consistency with the QuikSCAT L2B data record, the effective swath width represented be the total number of wvc rows extends to 1900km. Thus, each wvc row contains 152 wvc pixels in the cross-track direction. Approximately the first and last 30 wvc pixels are null. As an artifact of the orbital inclination and instrument swath width, consecutive orbits will usually start to overlap poleward of ~47° latitude.

7.5 Related Products

All related data products are referenced here with accessible web links:

a) RapidScat: http://podaac.jpl.nasa.gov/datasetlist?ids=Collections&values=RAPIDSCAT

b) QuikSCAT: http://podaac.jpl.nasa.gov/datasetlist?ids=Platform&values=QUIKSCAT

c) SeaWinds on ADEOS-II: http://podaac.jpl.nasa.gov/datasetlist?ids=Platform&values=ADEOS-II

d) Oceansat-2: http://podaac.jpl.nasa.gov/datasetlist?ids=Platform&values=Oceansat-2

7.6 Data Quality Flags

The policy adopted within the processing algorithms and software design is to flag values that are out of range or to indicate a non-nominal condition. Except where otherwise noted, a "1" or "set" bit indicates an error or abnormal condition, and a "0" or "cleared" bit indicates a normal condition. Some informational flags may have a number of set bits under normal conditions. Quality flag bits are set at the beginning of processing and are cleared when tests are performed and passed. If abnormal conditions terminate processing early, some bits may remain set. Since the processor may curtail subsequent operations for the wind vector cell that failed the test, those bit flags that normally would be tested in subsequent code also retain their initialized value. Thus, the order in which bit flags are processed determines whether their values are meaningful.

The Wind Vector Cell Preparation algorithm operates on a row of WVC values, passed from the Grouping algorithm, one WVC at a time. This algorithm checks each WVC to determine the data counts (total and by beam), quality flags, and surface flags to determine if there is sufficient data of sufficient quality to perform wind retrieval. It then computes the centroid of the σ_o locations to give a WVC location (latitude/ longitude; the binning grid is essentially "thrown away" at this point), and passes the "good" data to the Wind Retrieval algorithm. Upon return from wind retrieval, the ambiguous wind vector data is placed in the Level 2B output buffer.

The impact-based autonomous IMUDH rain flag algorithm developed for SeaWinds on ADEOS-II using rain impact derived from AMSR is now used for rain-flagging the QuikSCAT and RapidScat wind vector cells in the Level 2B product. A more description of the IMUDH development from SeaWinds and AMSR is provided here: ftp://podaac.jpl.nasa.gov/allData/quikscat/L2B/v2/docs/MUDH_Description_V3.pdf.

The transfer of the IMUDH algorithm from SeaWinds to QuikSCAT and finally to RapidScat was expected to involve a transformation and subsequent validation based on expected differences between the IMUDH parameters for the two instruments. This transformation step turned out to be unnecessary; the statistics of the IMUDH parameters for SeaWinds, QuikSCAT, and RapidScat are nearly identical. It was found that the SeaWinds IMUDH algorithm table and spatial filter parameters could be transferred directly, and identically, to QuikSCAT and RapidScat.

The primary improvement of IMUDH over MUDH is in the reduction of the overflagging of high wind speeds and the removal of swath artifacts including overflagging in the outer swath. The overall flagging rate for RapidScat is reduced from 5-6% to 1.92%, nearly identical to that of SeaWinds. This flagging rate was selected by examining various wind quality metrics for flagged and unflagged data with a variety of chosen flagging rates.

Users should note that the IMUDH algorithm was developed for the 25 km L2B only. For 12.5 km L2B products, the 25 km L2B IMUDH flags are applied to the corresponding cells of the 12.5 km data.

Quality of wind retrieval is based on the number and the quality of the σ_o measurements within the cell. If the Wind Retrieval Flag (bit 9) is set, then all of wind measurement parameters for the associated wind vector cell contain null values. The significance of each of the bit flags for the "flags" variable is described in Table 6.

Bit	**Definition**	**Bit Significance**
0	Adequate Sigma0 Flag	0 - Adequate good sigma0s available for wind retrieval.
		1 - Not enough good sigma0s available for wind retrieval.
1	Adequate Azimuth Diversity Flag	0 - Good azimuth diversity among sigma0s for wind retrieval.
		1 - Poor azimuth diversity among sigma0s for wind retrieval.

2-6	Reserved for future use	Always clear (0)
7	Coastal Flag	0 - No land mass was detected within the wind vector cell.
		1 - Some portion of the wind vector cell is over land.
8	Ice Edge Flag	0 - No ice was detected within the wind vector cell.
		1 - Some portion of the wind vector cell is over ice.
9	Wind Retrieval Flag	0 - Wind retrieval performed for wind vector cell.
		1 - Wind retrieval not performed for wind vector cell.
10	High Wind Speed Flag	0 - Reported wind speed is less than or equal to 30 m/sec.
		1 - Reported wind speed is greater than 30 m/sec.
11	Low Wind Speed Flag	0 - Reported wind speed is greater than or equal to 3 m/sec.
		1 - Reported wind speed is less than 3 m/sec.
12	Rain Flag Usable	0 – Rain flag for the wind vector cell is usable.
		1 – Rain flag for the wind vector cell is not usable.
13	Rain Flag	0 – Rain flag algorithm does not detect rain.
		1 – Rain flag algorithm detects rain.
14	Available Data Flag	0 – Inner beam data with QuikSCAT view forward and aft and outer beam data with QuikSCAT view forward and aft are available.
		1 – Data from at least one of the four possible beam and view combinations are not available.
15	Spare	Always clear (0)

Table 6: Comprehensive listing of quality flags and descriptions from the "flags" variable.

There's an additional quality flag variable called "eflags". The "eflags" variable is meant to help provide additional support to users who may be concerned with the quality of the rain corrections, which provides additional information including: whether the rain corrections were applied, whether the rain corrections produced a negative speed bias, or if the rain corrections were unusually large (i.e., producing a correction larger than 1 m/s). It also should be noted that the rain correction method was only optimized for wind speeds between 0 and 20 m/s, and it's a known issue that for wind speeds beyond 20 m/s the rain correction may often degrade the accuracy of the corrected wind speed. The significance of each of the bit flags for the "eflags" variable is described in Table 7.

Bit	Definition	Bit Significance
0	rain_correction_not_applied_flag	0 – Rain correction is applied. 1 – Rain correction is not applied.
1	correction_produced_negative_spd_flag	0 – Rain correction did not produce a negative wind speed. 1 – Rain correction produced a negative wind speed.
2	all_ambiguities_contribute_to_nudging_flag	0 – Less than 4 ambiguities were allowed during nudging. 1 - All 4 ambiguities were allowed during nudging.
4	large_rain_correction_flag	0 – Rain correction did not produce a significant wind speed bias. 1 – Rain correction produced a speed bias greater than 1 m/s.

Table 7: Comprehensive listing of quality flags and descriptions from the "eflags" variable.

8. Known Issues and Source of Error:

A grid cell location is defined to be the average centroid of the measurements used to retrieve wind in that cell. Latitude and longitude locations are computed for grid cells in which winds are not retrieved (i.e., null WVCs over land). Locations of WVCs without winds are determined independently of the measurement locations. For this reason, there is commonly a noticeable discontinuity in grid locations near land. The wind_obj dataset is included to provide information useful for data producers, but is not especially informative to users. Users should instead use the ambiguity_obj data set which contains the objective function values for all of the ambiguities.

Due to the multi-operational roles of ISS, disruptions in the data flow and data retrieval for RapidScat occur much more frequently than stand-alone remote sensing platforms. Users depending on the availability of data within the last 14 days are therefore advised to defer to the near-real time updates provided by the following link at NOAA for adequate and timely information regarding any planned or ongoing data outages: http://manati.star.nesdis.noaa.gov/rscat_images/monitor/RapidScat_Scheduled_Outages.txt

Beginning on 15 August 2015, an anomalous drop in the echo power signal in the receiver resulted in a corresponding drop in the signal-to-noise ratio (SNR) that was substantial enough to impact data quality, particularly in low wind speed regimes (3 to 6 m/s) and in rain-contaminated regimes due to the lack of passive rain rate retrievals which are required for IMUDH and rain correction to the wind speeds. The SNR has sporadically meandered to nominal levels and then back to a low SNR state for reasons that are not yet fully understood. The SNR transitions are not preventable or predictable at this time. Other low SNR states, such as what took place on 10 February 2016, seem to have contributed to a calibration anomaly that resulted in a negative wind speed bias of 1 m/s across all wind speed regimes, however the precise cause and attribution of this bias has not been fully diagnosed. In such instances of low SNR states which affect the nominal science data quality of the L2B wind retrievals, measures have been taken to re-process segments of the impacted data time series to mitigate and partially correct for any biases and errors that have been introduced.

More on SNR conditions and other significant known issues affecting the data quality are tracked here: ftp://podaac.jpl.nasa.gov/allData/rapidscat/L2B12/v1.1/README.txt

Concerned data users should also strongly consider registering to the PO.DAAC email list by contacting podaac@podaac.jpl.nasa.gov to received timely updates regarding any significant data outages or data flow disruptions due to a data quality concern.

9. Data Access:

9.1 Obtaining Data, Documentation and Read Software:

The data, read software, and documentation are freely available for public download via anonymous FTP and OPeNDAP. For immediate access, please visit:

a) FTP: ftp://podaac.jpl.nasa.gov/allData/rapidscat/L2B12/

b) OPeNDAP: http://opendap.jpl.nasa.gov/opendap/allData/rapidscat/L2B12/

Note: the documentation (/doc) and read software (/sw) are located one directory level above the /v3 data directory.

All data granules are compressed using the industry standard GNU Zip compression utility. To learn more about the GNU compression utility, please visit the GZIP home page: http://www.gzip.org/.

MD5 checksum files are also available in the data directories to assist you in verifying the integrity of each data file/granule. To learn more about MD5 checksums, please visit: http://en.wikipedia.org/wiki/MD5

For general news, announcements, and information on this and all other ocean and sea ice data sets available at PO.DAAC, please visit the PO.DAAC web portal:

http://podaac.jpl.nasa.gov/

9.2 Contact Information:

Questions and comments concerning QuikSCAT Version 3 L2B should be directed to the Physical Oceanography Distributed Active Archive Center (PO.DAAC) at the NASA Jet Propulsion Laboratory (JPL). Please note that email is always the preferred method of communication.

E-Mail: podaac@podaac.jpl.nasa.gov

WWW: http://podaac.jpl.nasa.gov/DATA_CATALOG/ccmpinfo.html

Mail: PO.DAAC User Services Office

Jet Propulsion Laboratory

M/S T1721-202

4800 Oak Grove Drive

Pasadena, CA 91109

10. Read Software:

Sample software readers are currently available in IDL, MATLAB, R and Python at: ftp://podaac.jpl.nasa.gov/allData/quikscat/L2B12/sw/netcdf

11. Citation:

Citation of this dataset should follow the following formats, which depend on the version of the dataset being used.

11.1 Version 1 L2B NetCDF Dataset:

RapidScat Project. 2013. RapidScat Level 2B Ocean Wind Vectors in 12.5km Slice Composites. Ver. 1. PO.DAAC, CA, USA. Dataset accessed [YYYY-MM-DD] at http://podaac.jpl.nasa.gov/dataset/RSCAT_LEVEL_2B_OWV_COMP_12_V1.

11.2 Version 1.1 L2B NetCDF Dataset:

RapidScat Project. 2015. RapidScat Level 2B Ocean Wind Vectors in 12.5km Slice Composites Version 1.1. Ver. 1.1. PO.DAAC, CA, USA. Dataset accessed [YYYY-MM-DD] at http://dx.doi.org/10.5067/RSX12-L2B11.

11.3 General Data Citation Information

For more information on how to cite PO.DAAC data in presentations or publications, please read:

http://podaac.jpl.nasa.gov/CitingPODAAC

12. References:

A majority of the document material was provided by Bryan Stiles and Alex Fore, both through direct co-authorship and oral communication. This document also contains recycled material from previous QuikSCAT user guides. The references below pertain to peer-reviewed publications which formulated the basis for a substantial amount of the material within the *Processing Methodology* and *Calibration and Validation* sections of this guide document. Please be cautioned that this is not a complete list of peer-reviewed references, but merely what is considered at the present time to be the most authoritative and contemporaneous basis of fundamental knowledge pertaining to the creation and validation of the RapidScat L2B data record.

[1] Fore, A.G., B. W. Stiles, A.H. Chau, A.H., B.A. Williams, R.S. Dunbar, E. Rodríguez, "Point-wise Wind Retrieval and Ambiguity Removal Improvements for the QuikSCAT Climatological Data Set," Accepted for publication in IEEE Trans. Geoscience and Remote Sensing. doi:10.1109/TGRS.2012.2235843, 2013.

[2] Stiles, B.W., B. Pollard, and R.S. Dunbar, "Direction interval retrieval with thresholded nudging: a method for improving the accuracy of quikscat winds," Geoscience and Remote Sensing, IEEE Transactions on, vol. 40, no. 1, pp. 79–89, doi:10.1109/36.981351, 2002.

[3] B.W. Stiles; Danielson, R.E.; Poulsen, W.L.; Brennan, M.J.; Hristova-Veleva, S.; Tsae-Pyng Shen; Fore, A.G., "Optimized Tropical Cyclone Winds From QuikSCAT: A Neural Network Approach," Geoscience and Remote Sensing, IEEE Transactions on , vol.52, no.11, pp.7418,7434, Nov. 2014 doi: 10.1109/TGRS.2014.2312333

[4] B. W. Stiles, and Dunbar, R S., "A Neural Network Technique for Improving the Accuracy of Scatterometer Winds in Rainy Conditions," IEEE Transactions on Geoscience and Remote Sensing, 2010, Vol 48, No. 8, pp 3114-3122.

[5] Meissner, T.; Wentz, F.J., "Wind-Vector Retrievals Under Rain With Passive Satellite Microwave Radiometers," Geoscience and Remote Sensing, IEEE Transactions on , vol.47, no.9, pp.3065,3083, Sept. 2009 doi: 10.1109/TGRS.2009.2027012

13. Acronyms:

ADEOS: Advanced Earth Observing Satellite
ASCAT: Advanced Scatterometer (METOP)
CCSDS: Consultative Committee for Space Data Systems
CF: NetCDF Climate and Forecast (CF) Metadata Convention
DIR: Directional Interval Retrieval
ECMWF: European Centre for Medium-Range Weather Forecasts
ERS: Earth Remote Sensing
EUMETSAT: European Organization for the Exploitation of Meteorological Satellites
FTP: File Transfer Protocol
GMF: Geophysical Model Function
GMT: Greenwich Mean Time (also known as Zulu or UTC time)
H-Pol: Horizontally (HH) Polarized
IDL: Interactive Data Language
JPL: Jet Propulsion Laboratory
L2B: Level 2B
MD5: Message-Digest Algorithm
MetOp-A/B: Meteorological Operational Satellite series A and B (also METOP)
NASA: National Aeronautics and Space Administration
NetCDF: Network Common Data Form
OPeNDAP: Open-source Project for a Network Data Access Protocol
PO.DAAC: Physical Oceanography Distributed Active Archive Center
QuikSCAT: NASA Quick-recovery Scatterometer
RMS: Root-Mean-Square

SASS: Seasat-A Satellite Scatterometer
SSM/I: Special Sensor Microwave Imager
V-Pol: Vertically (VV) Polarized
WVC: Wind Vector Cell

14. Document History

14.1 Document Draft Date:

30 November 2014

14.2 Latest Document Revision Date:

18 November 2015

14.3 Change Log:

Revision	Date	Change Notes	Authors
1.0	29 March 2016	First release of user guide drafted and finalized.	David F Moroni, Bryan Stiles, Alex Fore. Additional inputs provided by Doug Tyler.

14.4 Document Location:

ftp://podaac.jpl.nasa.gov/allData/rapidscat/L2B12/docs/