QuikSCAT
Northward Near-Surface Wind (vas)

1. Intent of This Document and Point of Contact (POC)

1a) This document is intended for users who wish to compare satellite derived observations with climate model output in the context of the CMIP5/IPCC historical experiments. Users are not expected to be experts in satellite derived Earth system observational data. This document summarizes essential information needed for comparing this dataset to climate model output. References are provided at the end of this document to additional information for the expert user.

This NASA dataset is provided as part of an experimental activity to increase the usability of NASA satellite observational data for the model and model analysis communities. This is not a standard NASA satellite instrument product. It may have been reprocessed, reformatted, or created solely for comparisons with the CMIP5 model. Community feedback to improve and validate the dataset for modeling usage is appreciated. Email comments to HQ-CLIMATE-OBS@mail.nasa.gov.

Dataset File Names (as they appear on the Earth System Grid, or ESG):

vas_Amon_obs_Obs-QuikSCAT_obs_r1i1p1_199908-200910.nc
vasNobs_Amon_obs_Obs-QuikSCAT_obs_r1i1p1_199908-200910.nc
vasStderr_Amon_obs_Obs-QuikSCAT_obs_r1i1p1_199908-200910.nc

1b) Technical point of contact for this dataset: Rodriguez Ernesto,
Ernesto.Rodriguez@jpl.nasa.gov

2. Data Field Description

Climate and Forecast (CF) variable name, units:	vas, m s^{-1} vasNobs, number of observations vasStderr, m s^{-1}
Spatial resolution:	1° x 1°
Temporal resolution and extent:	Monthly, August 1999 to October 2009
Coverage:	Global, excluding sea ice regions

3. Data Origin

The data used to make this product was the Level 2B along-track gridded 25 km resolution scatterometer wind data (2006 reprocessing version using the QSCAT-1 geophysical model function), produced by the NASA QuikSCAT project and distributed by JPL's Physical Oceanography DAAC [1].

The SeaWinds instrument on QuikSCAT is an active microwave scatterometer designed to measure electromagnetic backscatter from a wind roughened ocean surface. The SeaWinds instrument uses a rotating dish antenna with two conically rotating pencil beams to acquire multiple measurements of backscattered power from different viewing geometries. The antenna emits microwave pulses at a frequency of 13.4 GHz (Ku-band) across broad regions of the Earth's surface. The instrument collects data over ocean, land, and ice in 1,800 kilometer wide swaths covering approximately 90% of the Earth's ice-free oceans each day. The microwave pulses emitted by the instrument are scattered by small-scale waves (i.e., capillary waves), which are in near equilibrium with the wind and thereby react quickly to surface wind changes. Modulation of the waves due to the wind alters the surface roughness of the ocean, affecting the normalized radar cross section (σ_0) and hence the magnitude of the backscattered power received by the instrument. Therefore, σ_0 can be empirically related to wind through a geophysical model function (GMF), which describe the relationship between σ_0, wind speed, wind direction, and radar imaging geometry [2]. Wind speed is obtained through GMF inversion using σ_0 and wind direction.

The Level 1A processing functions include time tagging of science telemetry frames, assignment of ephemeris and altitude information to each frame, conversion of data to engineering units, and extraction of calibration pulse data [2, p14]. The computation of σ_0 is performed for each power measurement provided in the Level 1A data [2, p16]. The radar signal is attenuated as it passes through the Earth's atmosphere. To correct for this effect, an atmospheric attenuation correction, based on the climatology provided by Wentz (1996), is applied to the σ_0 values. In SeaWinds L2A processing, the monthly 1° by 1° mean two-way nadir attenuation is spatially and temporally interpolated to the σ_0 location and converted to a line-of-sight attenuation.

Although it is well known that σ_0 is more closely related to wind stress than 10 m winds [12,13], the lack of sufficient *in situ* stress measurements for training has led the scatterometer community to adopt the notion of "equivalent neutral winds" [11]. "Equivalent neutral winds" are 10 m surface winds that would be observed under neutral stability conditions or atmospheric stratification (i.e., sea surface temperature equal to air temperature at the air-sea interface). Although "equivalent neutral winds" are closely related to 10 m winds, they are not identical. As a good rule of thumb, a 0.2 m/s global bias exists between the two wind retrievals [14], but some regional differences may also be present. For this data set, there was no attempt to correct the difference between neutral and 10 m winds.

The radar backscatter (σ_0) GMF describes the state of the scattering surface observed at a particular geometry (azimuth, incidence angle). Two or more observations at different look angles are required to determine a finite set of wind vector solutions. The upwind-downwind modulation of σ_0, coupled with at least three collocated observations of σ_0 differing in azimuth angle and/or incidence angle, in principle allows determination of a unique wind vector. The SeaWinds wind retrieval algorithm uses a maximum-likelihood estimator (MLE) as the objective function for determining wind vector solutions. Due to the azimuthal variation of the model function, the objective function used to determine wind vector solutions has a number of local extrema, referred to as "ambiguities". The SeaWinds ambiguity removal algorithm called DIRTH (Direction Interval Retrieval with Threshold Nudging) [10] is used to derive an optimal pair of estimated wind speed and direction from the multiple ambiguities to provide the "selected" wind vector.

To obtain the monthly, 1° gridded zonal (uas) and meridional (vas) wind components, the QuikSCAT L2B along-track gridded wind speed and direction data were quality-controlled by selecting only the most trustworthy data using the provided L2B data quality flags. A datum was rejected if it was potentially contaminated by rain, ice, and land or if the quality of the retrieval was otherwise questionable. The resulting set of wind speed and directions were converted to zonal (uas) and meridional (vas) surface winds using the relationships: uas=wind_speed*sin(wind_direction), vas=wind_speed*cos(wind_direction). Note that the reported wind direction is referenced to north using the oceanographic conventions (i.e., the flow vector represents the wind-to direction, rather than the wind-from direction). The data (wind_speed, uas, and vas) were then binned into 0.25° bins in latitude and longitude (bin boundaries starting at -90° for latitude and 0° for longitude) and monthly time intervals. The initial 0.25° bin resolution was chosen to be compatible with the intrinsic resolution of the 25 km L2B data. The calendar used was the actual standard calendar. For each 0.25° bin (lat,lon,month), the following were computed: a) nobs, number of valid observations; b) <uas>, <vas>, and <wind_speed>, 0.25° bin average of the zonal and meridional wind components and of the wind_speed; c) standard error. 1° bin values for these quantities were formed by weight averaging over 4 cells around the reported 1° bin center location. The weighting for each quantity was the number of observations in each subcell (i.e., the 0.25° bins), and the total number of observations was the sum of the number of observations in each subcell.

The standard error calculation does not necessarily reflect the uncertainty of the measurement. The calculation assumes the measurements are independent whereas they actually depend both on the satellite (orbits period, …) and the instrument (viewing angle, swath, scan frequency, …). The following section describes the uncertainty estimates.

4. Validation and Uncertainty Estimate

The accuracy of the SeaWinds scatterometer vector winds have been assessed through comparison with ship observations [3], buoy data [8,16], and numerical weather prediction models [8,13].

Figures 1 and 2 [8] summarize the performance of QuikSCAT against buoys and NWP models. In general, wind speeds are relatively unbiased from ~ 3 to 18 m/s, with significant uncertainty for wind speeds greater than 20 m/s. The wind direction is relatively unbiased for wind speeds greater than ~ 7 m/s, with an error of ~ 15^o that increases at lower winds. The error characteristics of the wind speed and direction are dependent on the cross-track distance from the nadir satellite path, with the best performance in between the nadir and far swath regions. Chelton and Freilich [8] concluded that QuikSCAT data have component error magnitudes of about 0.75 m/s in the along-wind direction (approximately north-south) and 1.5 m/s in the crosswind direction (approximately east-west). These results are consistent with other independent validations.

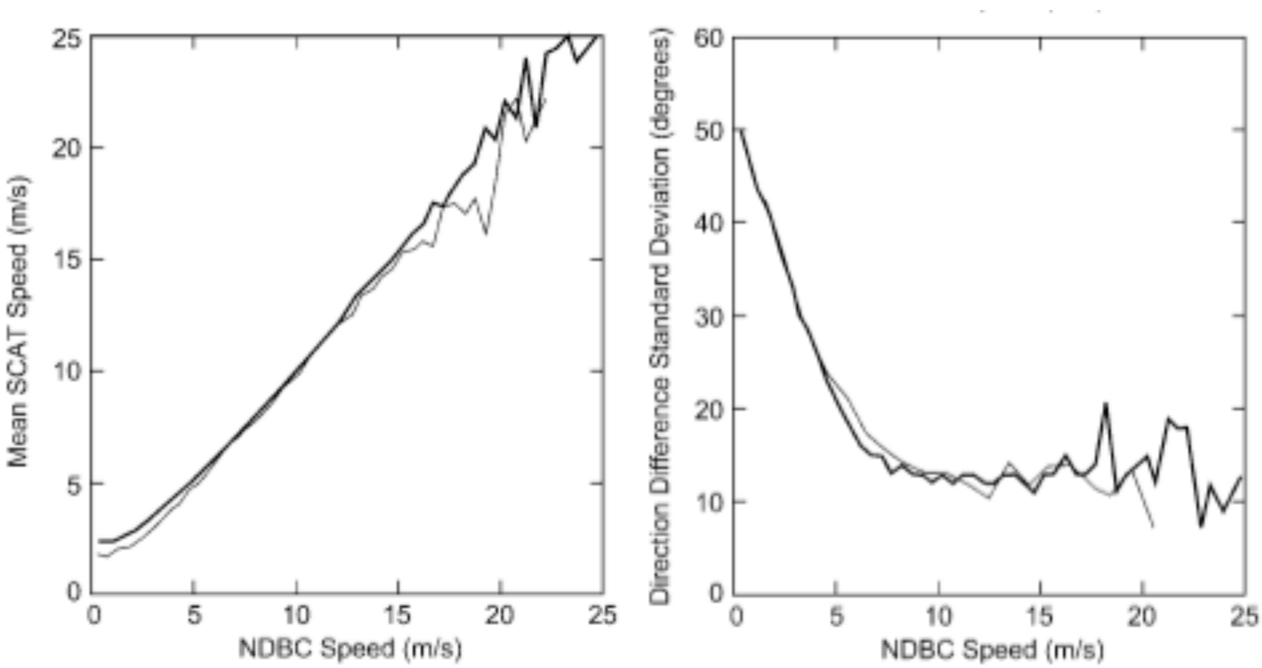

Figure 1: NSCAT (thin lines) and QuikSCAT (heavy lines) wind speeds and directions compared with collocated buoy measurements: (left) conditional mean scatterometer speeds binned on buoy speed, and (right) standard deviations of buoy minus scatterometer wind direction differences as a function of buoy wind speed. Only collocated measurements for which the buoy and scatterometer directions differed by less than 90° were considered. The noisiness at higher wind speeds is likely attributable to statistical uncertainties owing to the much smaller number of collocations at high wind speeds. (From Chelton and Freilich, 2005 [8])

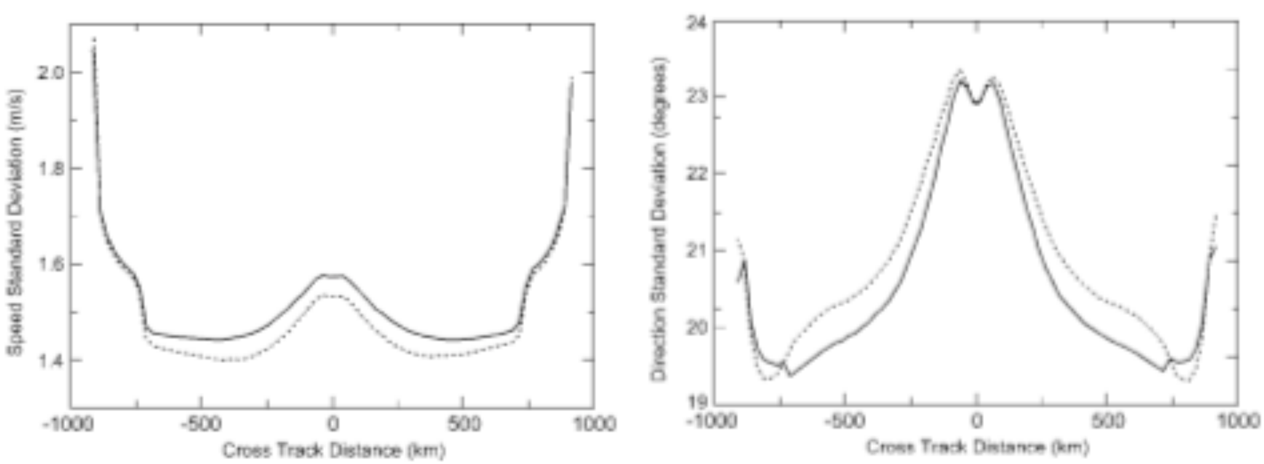

Figure 2: Cross-swath variations in comparisons between QuikSCAT measurements and spatially and temporally interpolated ECMWF (solid lines) and NCEP (dashed lines) 10-m wind analyses: (top) standard deviations of wind speed differences, and (bottom) standard deviations of wind direction differences. Only collocated measurements for which QuikSCAT and NWP wind directions differed by less than 90° were considered. (From Chelton and Freilich, 2005 [8])

5. Considerations for Model-Observation Comparisons

Equivalent Neutral vs 10 m Winds: This process of inference requires a geophysical model function (GMF) which relates σ_0 to 10 m equivalent neutral wind speed and wind direction, rather than actual 10 m speed and direction. As described above, this process is empirical. After correction for stability conditions, direct comparisons with buoys have shown that the estimates are unbiased. However, as discussed above, a global speed bias of about 0.2 m/s will occur if the stability corrections are not applied.

GMF uncertainty: Due to lack of training samples or instrument limitations, the GMF is not well known at very high winds (above 20 m/s) or very low winds (below 3 m/s). However, use of different GMF's has shown to have little effect on climatologies, such as the one in this data set.

All-Weather Measurement Capabilities: While QuikSCAT can operate successfully under cloudy and light-rain conditions, it is severely limited in the heavy rain conditions found in tropical cyclones [4, p6], and more importantly for this climatology, for any rainy conditions at low winds, such as those occurring in the tropics. To mitigate the rain effect, the QuikSCAT rain flag has been used to remove potentially contaminated measurements. This has led to a significant reduction in the number of samples in the tropics. In addition, the rain flagging procedure is not perfect and some residual rain effects may still be present in the tropics.

Sea-Ice and land contamination: As with rain, sea ice and land both contaminate the scatterometer signal. Both are flagged in the data, but the flags are not perfect. In order to avoid these sources of contamination, the current data set only reports data that have valid 1° gridded data for the entire span. This eliminates some areas that are covered by sea ice seasonally and some areas around small islands. There is one uniform data mask for the entire data set.

Temporal aliasing: Due to its sun-synchronous orbit, QuikSCAT revisits locations on the ground at around 6am or 6pm. This means that semi-diurnal wind variations are directly aliased into the mean climatology values. Semi-diurnal wind variations over the ocean have been observed in buoy and model data [17, 18], especially over the tropics and subtropics, and their magnitude must be considered when comparing between models and observations (unless the models are sampled in the same way as the observations). The contamination of diurnal variations, on the other hand, is relatively small since they tend to cancel due to the approximate 12-hour sampling.

6. Instrument Overview

NASA's Quick Scatterometer (QuikSCAT) was launched at 7:15 p.m. Pacific Daylight Time on Saturday, June 19, 1999 atop a U.S. Air Force Titan II launch vehicle from Space Launch Complex 4 West at California's Vandenberg Air Force Base [5]. The SeaWinds instrument on the QuikSCAT satellite is a specialized Ku-band microwave scatterometer that measures near-surface wind speed and direction under all weather and cloud conditions over Earth's oceans [2]. QuikSCAT collected ocean vector wind data until its antenna stopped spinning on the last week of November 2009.

The QuikSCAT satellite was launched into a sun-synchronous, 803-kilometer, circular orbit with a local equator crossing time at the ascending node of 6:00 A.M. plus or minus 30 minutes [2, p7]. It has a recurrent period of 4 days (57 orbits) while its orbital period is 101 minutes (14.25 orbits/day).

The nadir axis serves as the spin axis of the antenna dish, so that the radar mapping is achieved by a helical scan of surface swath by the beam. This is often referred to as a pencil beam scatterometer, and is the approach employed by SeaWinds [7]. The SeaWinds antenna footprint is an ellipse approximately 25-km in azimuth by 37-km in the look (or range) direction.

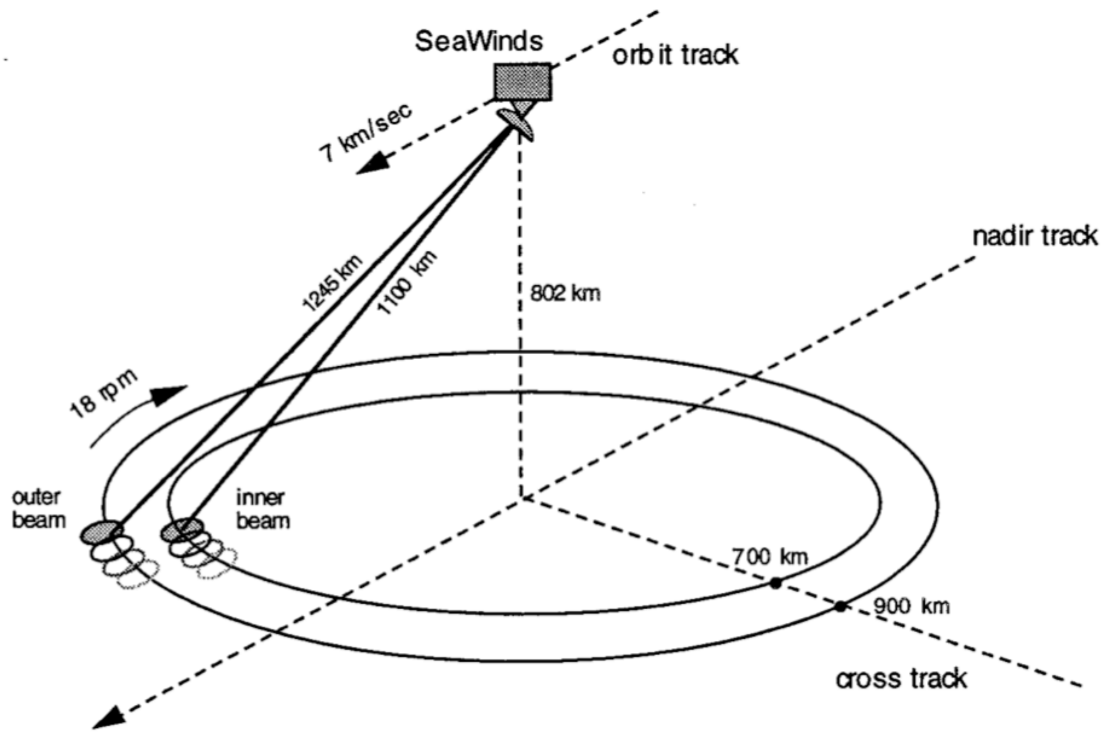

Figure 1: [6]

The basic pencil-beam scatterometer geometry used to build an 1800-km swath involves two beams with slightly different incidence angles to circularly scan about the nadir direction. Every point in the swath is visited from several different directions, allowing the retrieval of both wind speed and directions [4, p19].

To retrieve unambiguous wind of a surface resolution cell, called a wind vector cell (WVC), a scatterometer needs to illuminate the cell at a minimum of four azimuthal angles. Using two beams, each spot in the primary radar mapping swath, which is defined by the swath diameter of the inner beam, will be viewed from four azimuth/look directions, namely, the fore/aft views at the two elevations; as illustrated in Fig. 2 [7]. At surface locations imaged by both beams, backscatter measurements from four geometries within a time interval of less than 4.5 min can be collocated—one from each forward-looking beam and one from each aft-looking beam [8, p410].

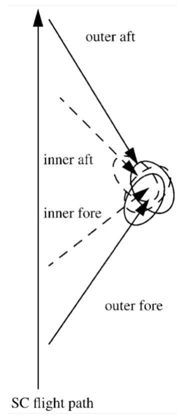

Figure 2: [7]

7. References

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[2] QuikSCAT Science Data Product User's Manual:

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http://podaac.jpl.nasa.gov/WEB_INFO/QFO_MissionConceptReport_JPL_08-18.pdf

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[17] C. Deser and C. Smith, “Diurnal and semidiurnal variations of the surface wind field over the tropical pacific ocean,” Journal of Climate, vol. 11, no. 7, pp. 1730–1748, 1998.

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8. Revision History

Rev 0 – Wednesday, April 11, 2012