# SeaWinds Scatterometer Real-Time Merged Geophysical Data Product

## User's Guide

Version 2.2.0

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14 February 2000

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# Preface

This is a preliminary user's guide for the SeaWinds Real-Time MGDR Data Product (SWS_Met MGDR). For this version we take advantage of the high quality, complete documentation that is available for the SWS_Sci algorithms and interfaces. In many respects the processing algorithms and data elements are identical for real-time and science data. Therefore the SWS_Met processing algorithms and data elements are not described here. Rather we reference the science data documentation, particularly the Science Algorithm Specifications [1], the Science Data Product User's Manual [13], and the Software Interface Specifications [14, 15, 16], describe differences, and highlight certain critical issues. It is envisioned that this document might be expanded at some later time. In this case, the sections describing the differences will be retained, as an aid to those users already familiar with the SWS_Sci. Note that there are important and critical differences between the SWS_Sci and the SWS_Met MGDR data products, and between the SWS_Met MGDR data products and the SWS_Met BUFR data products.

This is an evolving document. Version 2.0 was created quickly. We anticipate minor revisions in the near future. Please send corrections, comments, and suggestions to `rhoffman@aer.com`.

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# 1 Overview of SeaWinds Data Products

This document describes the SeaWinds Real-Time MGDR Data Product (SWS_Met MGDR). There are two other formats for SeaWinds data. These are the SeaWinds Science Data Product (SWS_Sci) [13], and the SeaWinds Real-Time BUFR Data Product (SWS_Met BUFR) [7]. Differences and similarities between the contents and formats of these three data sets are noted throughout this document. An overview of all three data sets follows.

The current release of these data is associated with several caveats. The user should be aware of the following:

- Wind performance in the far-swath is degraded due to the fact that only vertically polarized $\sigma^0$ values are used in the wind retrieval. This problem is exacerbated in the case of the SWS_Met MGDR and SWS_Met BUFR because only two $\sigma^0$ values are used.

- The SWS_Met MGDR and SWS_Met BUFR data processing use NCEP AVN forecasts to initialize the ambiguity removal, the SWS_Sci processing uses analysis fields. The forecasts used are short range, no more than 12 hours in length.

- The brightness temperature related quantities are all presently missing in the SWS_Met MGDR and SWS_Met BUFR. These will be filled in at some later time. In the science data sets only the L1B has brightness temperature information.

- At present, two rain flag algorithms have been implemented, based on the $\sigma^0$ measurements and tuned to SSM/I rain estimates. Indices and flags from these algorithms are included in the SeaWinds data sets. For the SWS_Met MGDR and SWS_Met BUFR, as further data is collected, we anticipate occasional updates to the rain flag calibration files in order to provide improved rain indicators. The current rain algorithms are not valid in the far-swath. No rain information is present in the far swath. A single unified rain flag will probably be implemented in the future.

The SeaWinds scatterometer provides both Earth-located radar backscatter ($\sigma^0$) and vector wind measurements collocated in $25 \times 25\ km$ wind vector cells. This includes coverage over land and ice as well as oceans; wind vectors are only retrieved in the ocean cells. The SWS_Met data set is designed to address the needs of real-time operational users, and will normally be transmitted in BUFR format. The SWS_Sci is of higher quality, but will not be available in real-time, and is designed to address the needs of the scientific community.

The SWS_Sci is created by JPL and distributed by PO.DAAC. The SWS_Met MGDR is produced by NOAA/NESDIS, converted to SWS_Met BUFR and transmitted to operational users. The SWS_Sci data products are in HDF format. The SWS_Met MGDR data products are in binary format. The SWS_Met BUFR data products are in BUFR format.

The SWS_Met processing algorithms are identical to the science data algorithms [1] except that the SWS_Met data processing algorithms use WVC-composites, instead of pulses (*aka* eggs) or pulse-composites, of $\sigma^0$ measurements in the wind vector retrieval to meet operational latency requirements. (See Section 2.3 for details.) Since the algorithms are the same, the definitions of the data elements in the SWS_Sci, SWS_Met MGDR, and SWS_Met BUFR data products are in many cases the same. Detailed definitions of the wind vector data elements are given by the Level 2B Software Interface Specification (SIS) [16]. Similarly detailed definitions of the $\sigma^0$ data elements are given by the Level 2A SIS [15]. Differences between the SIS and the SWS_Met MGDR are described in Section 3.1.

For all three data formats, the SeaWinds data are organized in a swath-based format, with 76 cross track cells. Unlike NSCAT, there is no "nadir" gap for SeaWinds. The nominal instrument measurement swath extends 900 $km$ to either side of the nadir track. Thus, 72 WVCs, with 36 on either side of nadir, should accommodate nearly every $\sigma^0$ measurement. Variations in spacecraft attitude and the local curvature of the earth will cause very few $\sigma^0$ measurements to fall outside of the nominal measurement swath. To accommodate these measurements, the SeaWinds data products includes 4 additional WVCs per row, two on either side of the measurement swath, for a total of 76 WVCs. For each across swath position or cell, there are 1624 rows of WVCs, from the beginning to the end of each revolution (or rev). Since the cells are used to group $\sigma^0$ data for wind vector retrieval they are called wind vector cells. Nominally, there is a one-to-one correspondence between a file and a QuikSCAT rev for the SWS_Sci, and between a file and a pass for the SWS_Met MGDR. For the SWS_Met data products, a record corresponds to a single row of cells, i.e. to a single wind vector cell (WVC) row.

There are approximately 100 revs per week. The data products are moderately large, with weekly volumes of 2 gigabytes for the SWS_Met MGDR and $\sim$ 1 gigabyte for the SWS_Met BUFR.

There are several key differences between the conventions of the SWS_Sci, the SWS_Met MGDR, and the SWS_Met BUFR. These are noted where appropriate in the text and listed here:

**Missing values** are coded with a special missing value indicator in the SWS_Met BUFR, but are often set to zero in the SWS_Sci and SWS_Met MGDR.

**Wind direction** is meteorological for SWS_Met BUFR and oceanographic for the SWS_Sci and SWS_Met MGDR.

**Bit numbering** starts with one for the most significant bit for the SWS_Met BUFR, and with zero for the least significant bit for the SWS_Sci and SWS_Met MGDR. This affects documentation and data storage. This document follows the SIS bit numbering convention.

**Fixed ordering** is used to store the $\sigma^0$ data in the SWS_Met BUFR, but not in the SWS_Sci and SWS_Met MGDR.

**kp_gamma** is stored in decibels ($dB$) in the SWS_Met BUFR, but not in the SWS_Sci and SWS_Met MGDR.

In what follows, we refer to individual data elements by the corresponding SIS element names in this format: **wvc_quality_flag**.

Note that much of the material in section 2 is covered in greater detail in the Science Data Product User's Manual [13].

# 2 Technical Background

The SeaWinds instrument on QuikSCAT is a "quick recovery" mission to fill the gap created by the loss of data from the NASA Scatterometer (NSCAT), when the satellite it was flying on lost power in June 1997. QuikSCAT was launched from California's Vandenberg Air Force Base aboard a Titan II vehicle at 7:15 PDT, 19 June 1999, and will continue to collect important ocean wind data that was begun by NSCAT in September 1996. SeaWinds on QuikSCAT is depicted in figure 1.

SeaWinds uses a rotating dish antenna with two spot beams that sweep in a circular pattern. The antenna radiates microwave pulses at a frequency of 13.4 GHz across broad regions on the Earth's surface. The instrument will collect data over ocean, land, and ice in a continuous, 1,800-kilometer-wide band, making approximately 400,000 measurements and covering 90% of Earth's surface in one day (figure 2).

## 2.1 Science Motivation

The primary mission of QuikSCAT is to acquire all-weather high-resolution measurements of near-surface winds over the global oceans. These measurements will help to determine atmospheric forcing, ocean response and air-sea interaction mechanisms on various spatial and temporal scales. Operational users will visualize the wind data for nowcasting applications and will assimilate the wind data into numerical weather and wave-prediction models. QuikSCAT wind data, combined with measurements from various scientific disciplines, will help to understand mechanisms of global climatic change and weather.

Satellite scatterometers are microwave radar instruments designed specifically to measure near-surface wind velocity (both speed and direction) over the global oceans under all weather conditions [11, 3]. 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 models, improving our ability to predict future weather. As the only remote sensing systems able to provide accurate, frequent, high-resolution measurements of ocean surface wind speed and direction under both clear sky and cloudy conditions, scatterometers have played an increasingly important role in oceanographic, meteorological and climatic studies since the launch of ERS–1 in 1991. Scatterometers use a highly indirect technique to measure wind velocity over the ocean. The atmospheric motions themselves do not substantially affect the radiation emitted and

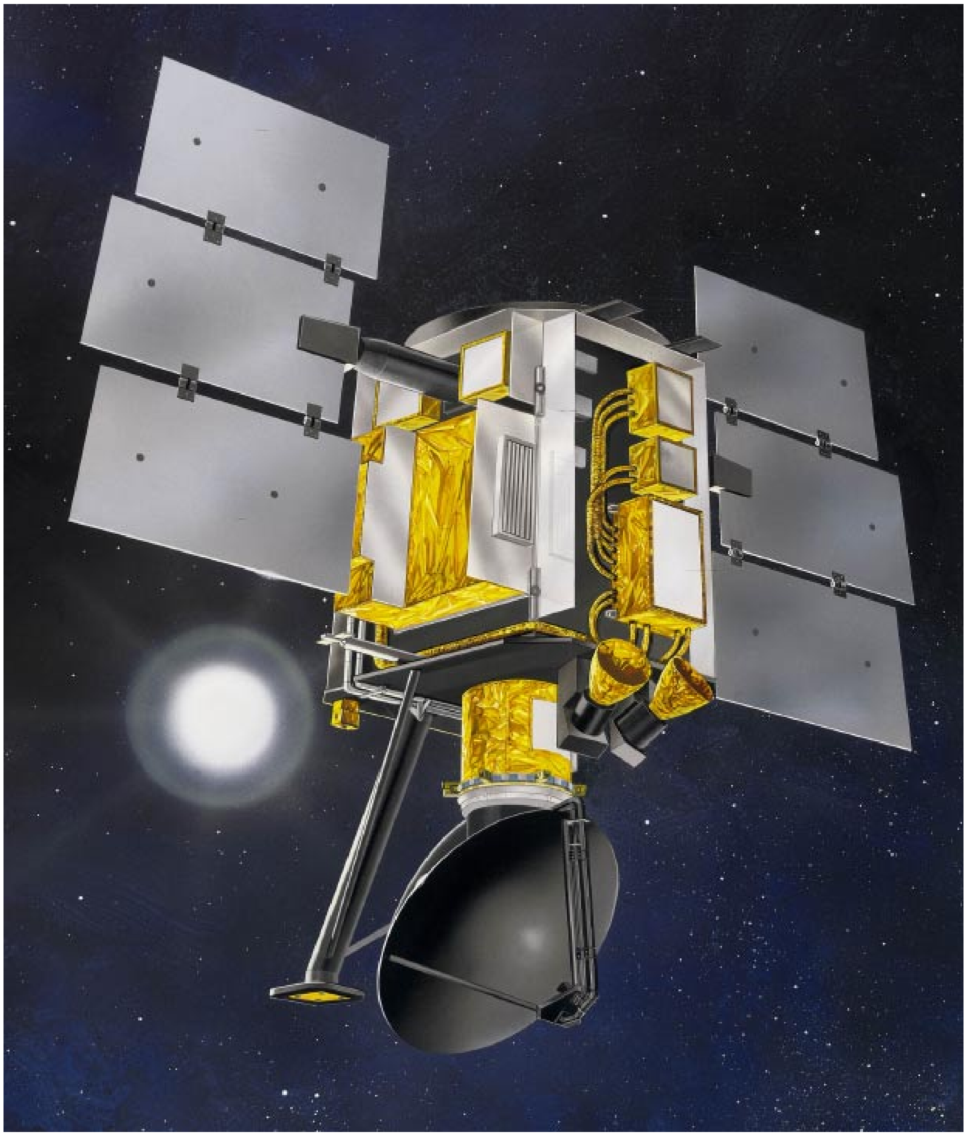

Figure 1: Artists depiction of SeaWinds on QuikSCAT.

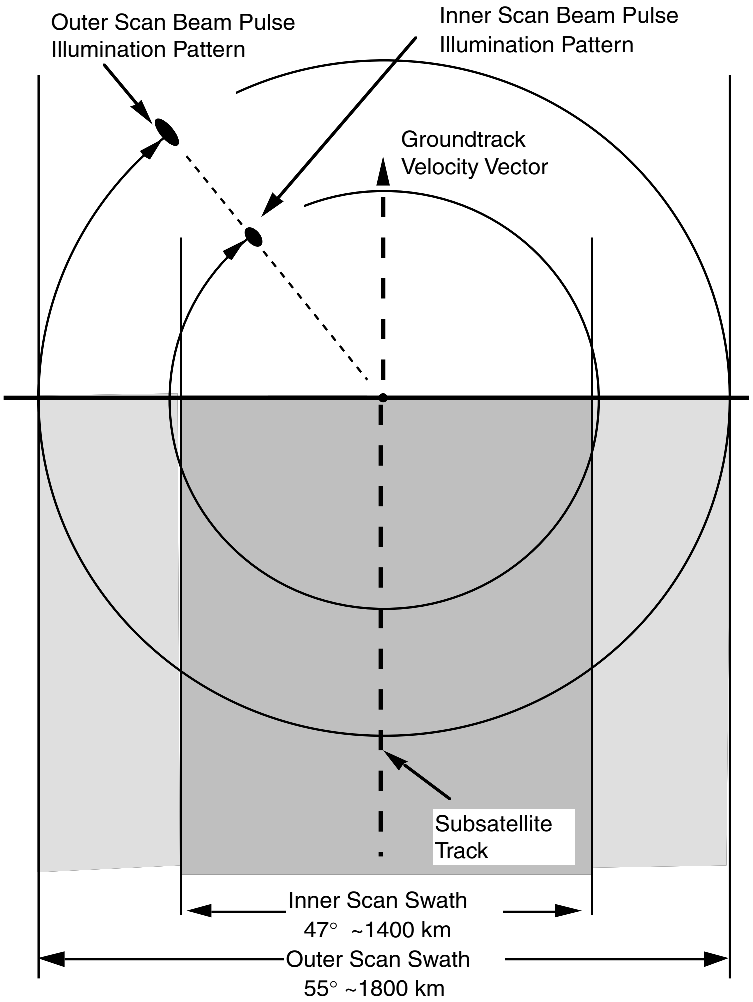

Figure 2: The SeaWinds swath.

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 ($\sigma^0$) of the sea surface. Backscatter cross section varies with both wind speed and direction when measured at moderate incidence angles. Multiple, collocated, nearly simultaneous $\sigma^0$ measurements acquired from several directions can thus be used to solve simultaneously for wind speed and direction.

## 2.2 QuikSCAT Mission Description

For the QuikSCAT SeaWinds mission the science objectives are:

- Acquire all-weather, high-resolution measurements of near-surface winds over global oceans.
- Determine atmospheric forcing, ocean response, and air-sea interaction mechanisms on various spatial and temporal scales.
- Combine wind data with measurements from scientific instruments in other disciplines to help us better understand the mechanisms of global climate change and weather patterns.
- Study both annual and semi-annual rain forest vegetation changes.
- Study daily/seasonal sea ice edge movement and Arctic/Antarctic ice pack changes.

The operational objectives are:

- Improve weather forecasts near coastlines by using wind data in numerical weather- and wave-prediction models.
- Improve storm warning and monitoring.

The mission description includes:

- Launch vehicle is Titan II.
- Mission life is 2 years (3 years consumables).
- Orbit is sun-synchronous, 803 $km$ altitude above the equator, with an inclination of 98.616°. The orbit repeats every 4 days or 57 orbits. The orbital plane is perpendicular to the sunlight—local time is always close to 6 am/pm and the spacecraft is rarely in the earth's shadow.

The spacecraft description includes:

- ADCS approach is 3-axis stabilized, and uses star tracker/IRU/reaction wheels, and C/A code GPS.
- Pointing accuracy is $< 0.1^\circ$ absolute per axis.
- Pointing knowledge is $< 0.05^\circ$ per axis.
- Telecommunications include 2 Mbps S-band P/L for science data and 5, 16, 256 Kbps S-Band and 2 Kbps S-Band uplink for housekeeping data.
- Propulsion is N2H4 blowdown.
- Mass is 970 $kg$.
- Orbital average power is 874 $W$.
- Data capacity is 8 gigabits.

The ground system includes:

- Tracking is by the Earth Polar Ground stations Svalbard, Norway; Poker Flats, Alaska; Wallops Island, Virginia; and McMurdo, Antarctica.
- High-quality research data products are produced at JPL and distributed to the science community within 2 weeks of receipt.
- Scatterometer SWS_Sci are distributed by the JPL Physical Oceanography Distributed Active Archive Center (PO.DAAC), a scientific data distribution site: `http://podaac.jpl.nasa.gov`.
- Operational data products produced at National Oceanic and Atmospheric Administration (NOAA) for international meteorological community within 3 hours of data collection. The operational timeline is summarized in Table 1.

The instrument description includes:

- 13.4 $GHz$ radar, emitting 110 $W$ pulses at 189 Hertz repetition frequency.
- 1 $m$ diameter rotating dish antenna that produces two spot beams, sweeping in a circular pattern.
- Mass is 200 $kg$.
- Power is 220 $W$.
- Average data rate is 40 kilobits per second.

The measurements description includes:

- 1800 $km$ swath during each orbit provides approximately 90% coverage of Earth's oceans every day. After crossing the equator, the next equator crossing occurs 101 minutes later 2800 $km$ to the west. The local time at the ascending node is within 30 minutes of 6.00 am.
- Wind-speed measurements of $3 - 20\ m/s$, with an accuracy of $2\ m/s$; direction, with an accuracy of 20°.
- Wind vector resolution of 25 $km$.
- Geolocation accuracy is $\sim 1\ km$; incidence angle accuracy is $< 0.05°$; and azimuth angle accuracy is $\sim 0.01°$.

The mission partners are:

- National Oceanic and Atmospheric Administration (NOAA);
- NASA Goddard Space Flight Center (GSFC);
- Ball Aerospace and Technologies Corporation;
- U.S. Airforce and Missile Systems Center;
- Honeywell Satellite Systems Operations;
- Raytheon E-Systems Corporation;
- Lockheed Martin Astronautics; and
- Hughes Electron Dynamics Division.

The SeaWinds/QuikSCAT project is managed for NASA's Earth Science Enterprise by the Jet Propulsion Laboratory, a division of the California Institute of Technology.

Table 1: Operational QuikSCAT data flow timeline in minutes.

| **Time (min)** | **Description** |
|---|---|
| 101 | Orbit |
| 10 | Data aquisition and telemetry processing |
| 27 | Data transfers |
| 35 | Geophysical data processing |
| 173 | Total |

## 2.3 SeaWinds Geophysical Data Processing

The SeaWinds geophysical data processing is summarized by figure 3. The Level Data products are produced by the SWS_Sci. The SWS_Met data processing follows the same steps, but does not create the Level Data products, except internally. Instead information from the L2A and L2B Data are combined in the SWS_Met MGDR, which is then translated to SWS_Met BUFR.

The term "wind retrieval" encompasses the process of inverting the geophysical model function [6, 17] for a given set of $\sigma^0$ values to obtain (multiple) maximum likelihood estimates of the wind speed and direction, and then selecting the final wind field from the derived solution set. The inversion process is performed in a point-wise fashion (assuming each wind vector cell to be independent of its neighbors), and yields multiple solutions (ambiguities) due to the azimuthal variation of the model function. The process of ambiguity removal is performed in a field-wise fashion; the baseline algorithm used by SeaWinds is a vector median filter [12].

The wind retrieval processing for the SWS_Met is identical to that used for the SWS_Sci, except that the number of $\sigma^0$ values are greatly reduced by creating "WVC-composites" of the "pulse-composites" nominally used in the science data processing. (Currently, the science data processing is based on full pulses.) Composites are formed by appropriately averaging finer grained $\sigma^0$ data. The averaging is weighted by the so-called "$X$-factor" so that returned power is in fact added. The definition of $X$ is simply that the returned power equals $\sigma^0 X$. The finest grained $\sigma^0$ data are slices. Each radar pulse is divided into slices by frequency chirping the emitted radar signal and applying an FFT decomposition to the returned signal. The effect is to divide the signal into different range/Doppler bins as shown in figure 4. The slices cover the swath densely (figure 5). Pulse-composites are averages of all slices within the WVC of a single radar pulse. WVC-composites, sometimes denoted "composites squared", are formed by averaging all slices (or equivalently all pulse-composites) within the WVC of a single "flavor". If the centroid of a slice is within a particular WVC, then the slice is considered to be within the WVC. (See figure 6.) There are four types of measurements or flavors—inner-foreward, outer-foreward, inner-aft, and outer-aft. Here inner and outer refer to the inner and outer scan beams with look angles of 39.876° and 45.890° resulting in approximately constant incidence angles at the earth's surface of 45° and 53.6°, respectively. Inner and outer are horizontally and vertically polarized respectively. Foreward and aft refer to beam footprints foreward and aft of the spacecraft. Note that in the far-swath there are only outer scan beam footprints, and thus only two flavors of $\sigma^0$. The SWS_Sci uses an arbitrary number of pulses or pulse-composites in each WVC. The SWS_Met processing uses a maximum of four WVC-composites in each WVC. Accurate wind retrieval requires a diversity of azimuth angles. SWS_Sci wind retrieval requires that the range of azimuth angles be at least 20°, otherwise no winds are retrieved. SWS_Met processing requires at least one foreward beam measurement and at least one aft beam measurement.

Since there are nominally four flavors of $\sigma^0$ values in the center of the swath, but only two in the far-swath, wind retrievals in the far-swath are expected to be of lower quality. Further, we may identify two zones within the inner-swath, which we call the mid-swath and

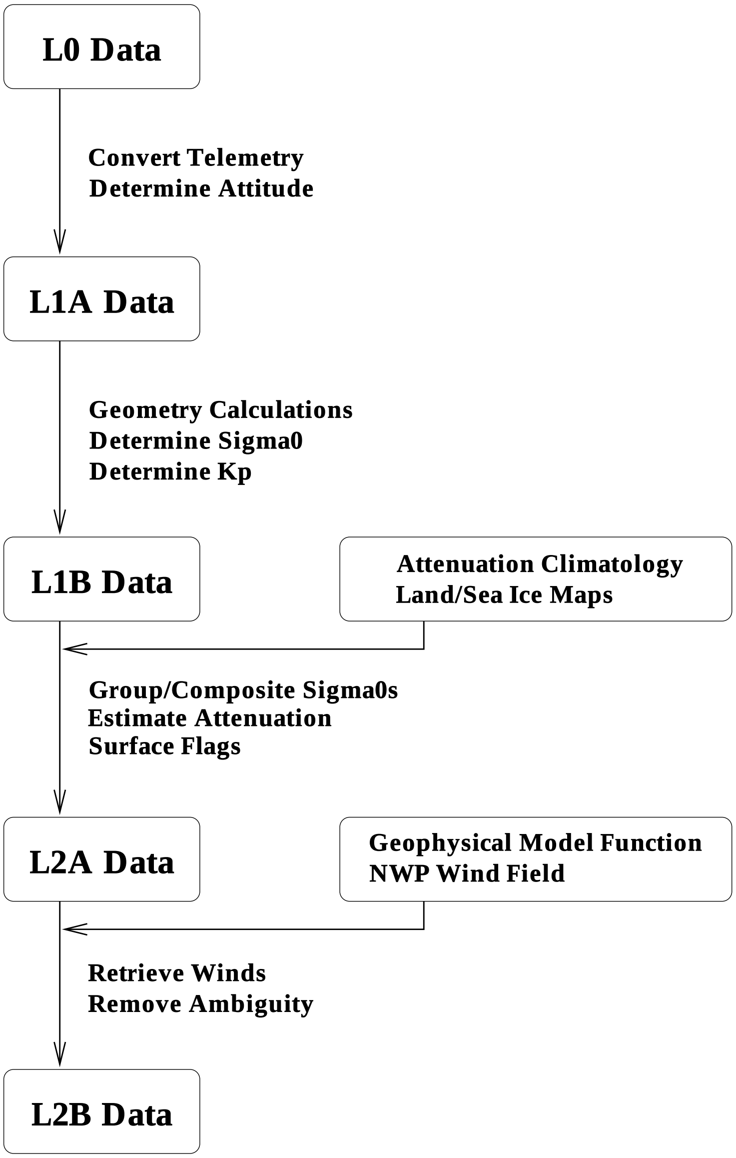

Figure 3: Data flow for SWS_Met data processing.

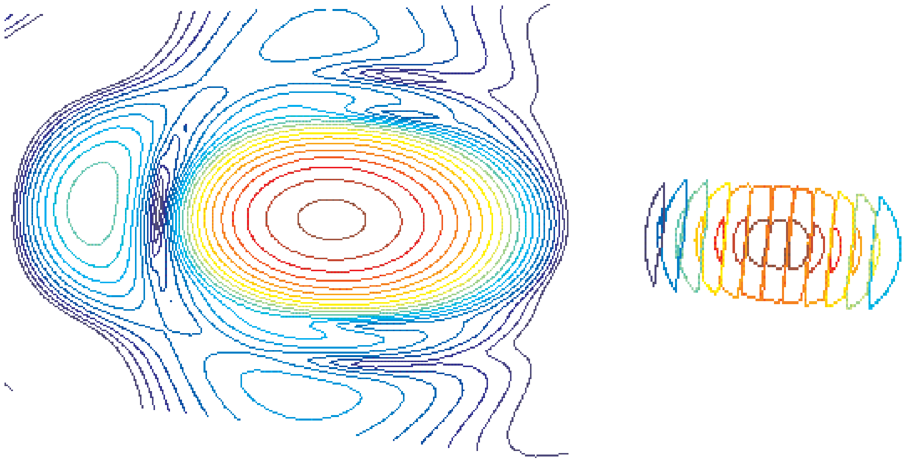

Figure 4: A pulse and its slices. The antenna response pattern for a single pulse is plotted with a contour interval of 1 $dB$ on the left. The corresponding slices are shown on the right at the same scale. Here the contour interval is 3 $dB$, and only one or two most significant contours are shown. The outer or guard slices are used only to monitor the noise characteristics of the instrument. Up to eight inner slices are used to estimate $\sigma^0$.

nadir-swath, of greater and lesser quality, respectively. The mid-swath ($\sim 200 - 500\ km$ on either side of the satellite track) has the greatest diversity of azimuth and incidence angles, and hence the best quality data. While no project requirements exist for the accuracy of the SWS_Met wind vectors, we expect the overall performance to be slightly degraded from that of the SWS_Sci primarily because creating the WVC-composites loses some of the azimuthal diversity of the original measurements. In particular, we anticipate that the resulting estimated likelihoods will be less skillful.

The ambiguity removal algorithm may be initialized with either the highest likelihood solutions (best-fits to the model function) or by comparison of the directions of the two most likely ambiguities in each WVC with a numerical weather product (NWP) analysis field.

## 2.4 Land and Ice Applications

Although the primary focus of the QuikSCAT mission is on ocean winds, there has been considerable interest and research into applications of scatterometer data to land and ice surfaces [10]. For instance, images generated from earlier scatterometer data have demonstrated the ability to discriminate tropical vegetation types [9], and have been useful in polar ice studies [8]. If the normalized radar cross section $\sigma^0$ in decibels is expressed in the form

$$\sigma^0 = A + B(\theta - 40),$$

where $\theta$ is the incidence angle of the measurements, images of $A$ and $B$ can be created from the measurements. These images show local and seasonal variations in the surface scattering

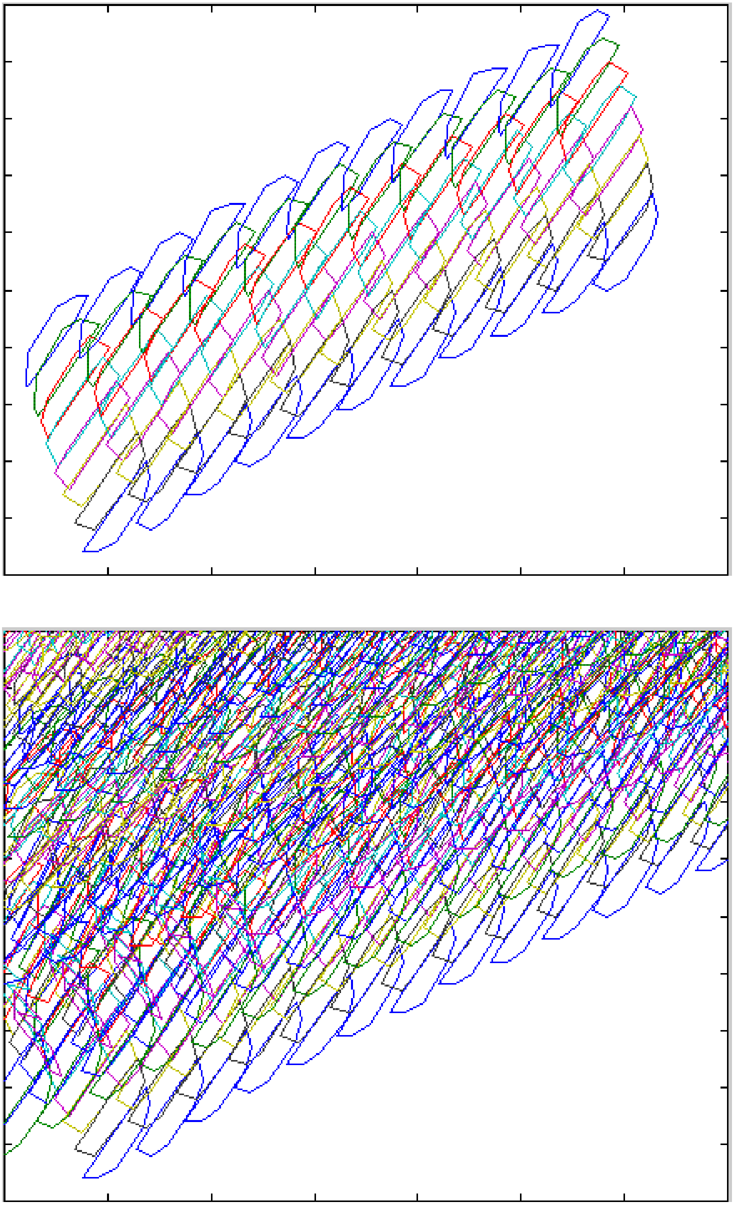

Figure 5: Slices simulated for the foreward inner beam for (top) a few pulses on a single scan line and (bottom) many pulses starting from the few shown above. The height of each panel corresponds to one degree of latitude or approximately 100 $km$. The slices are $\sim 25 \times 37$ $km$.

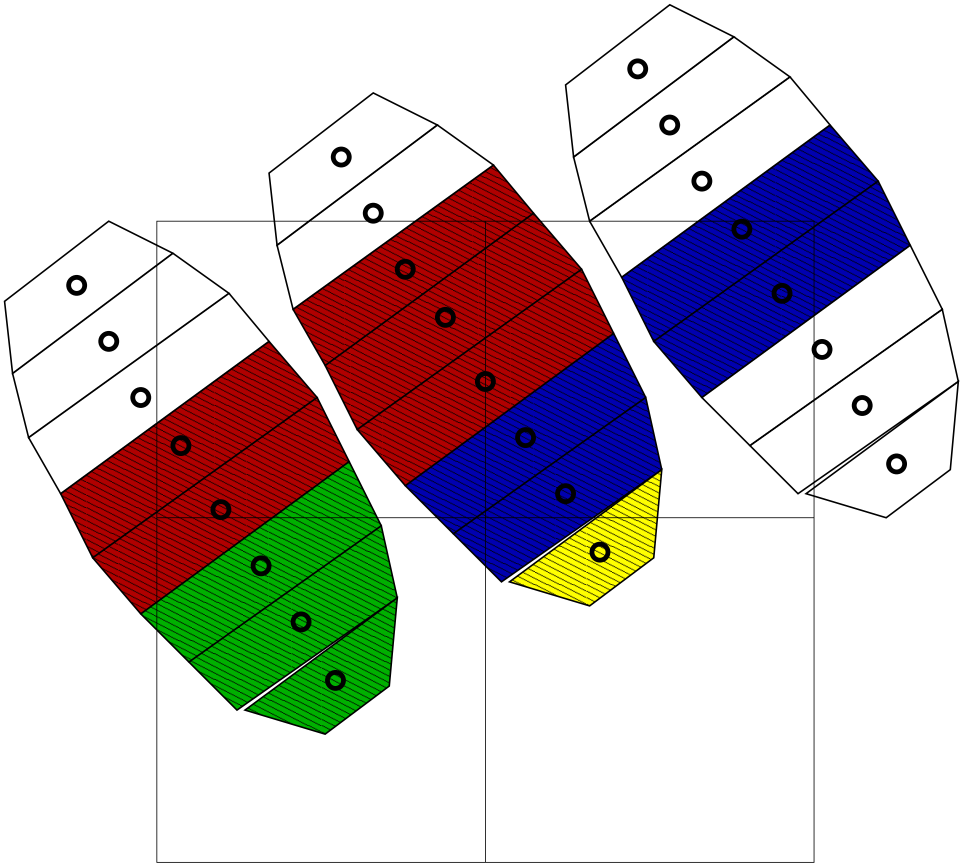

Figure 6: The slices for three pulses of a single flavor are shown along with four WVCs. The slices are shaded differently depending on which WVC contains the slice centroid. Slices with centroids outside the four WVCs are not shaded. All slices with the same shading contribute to the WVC-composite associated with that shading. Similarly all slices with the same shading from a single pulse contribute to the pulse-composites for that pulse and WVC.

which can be related to real geophysical effects. QuikSCAT will make it possible to study interannual variations in the radar response and identify long-term changes in the key surface features. The SeaWinds data products include the $\sigma^0$ data over land and ice surfaces, as well as ocean, to help monitor these geographical areas.

# 3 Data Content and Format

The $\sigma^0$ data are colocated and organized into WVCs. Wind ambiguities are retrieved for each WVC with sufficient $\sigma^0$ data. Each WVC has an along track row number and a cross track cell number. These indices define a grid which follows the satellite track. For data storage purposes, WVCs are collected into WVC rows. A WVC row contains all $\sigma^0$ and wind data for a given cross-track row or strip of WVCs. WVC rows with no $\sigma^0$ data are not stored. Conceptually, WVC rows may be organized into revs. Thus each WVC in the entire QuikSCAT mission may be uniquely identified by rev, row and cell number—except for WVCs over Antartica in the SWS_Sci (see Section 5.2).

The nominal measurement time for the $\sigma^0$ data in the record is the UTC time tag (**wvc_row_time**), which roughly corresponds to the time that the spacecraft nadir crosses the midpoint of the WVC row. Note that for land and ice WVCs, the wind vector data are missing.

Letter codes **M** and **D** are used to label list items in Section 3.1. **M** in square brackets indicates that the SIS data element definition is *modified* to be applied to the SWS_Met MGDR. **D** indicates a data element must be *defined* (because it is not defined by the SIS).

## 3.1 Modifications to the SIS Data Element Definitions

If a data element name used here is defined in either the Level 2A or Level 2B SIS then that definition is correct, with exceptions and modifications noted here. Definitions are also given below in Section 3.2 for any data element names not defined in the SIS.

All record elements associated with $\sigma^0$ values are modified in the sense that the elements are WVC-composites instead of pulse-composites. As with the $\sigma^0$ values, these other elements are also averaged or combined. These elements include those specifying the location, geometry, attenuation correction, $K_p$ coefficients, and flags. Numeric values are averaged using "$X$-factors" as weights. For $\sigma^0$, this corresponds to summing the returned power. Flags are combined by logical or-ing—if any pulse-composite used in the averaging has a flag set, the WVC-composite has the corresponding flag set. However, data with flags indicating poor quality will, for the most part, be excluded from the averaging procedure. Details of the data processing are described in the Science Algorithm Specifications [1]. NOTE that (both pulse and WVC) compositing ignores surface type. Nothing special is done when combining $\sigma^0$ values for composites straddling a land/sea or ice/sea boundary. These composites should not be used for wind retrieval. (Use **surface_flag** to check for land or ice.)

In using the SIS definitions for the SWS_Met MGDR, some SIS definitions require minor modifications:

**[M]** **build_id** identifies the version of the SWS_Met software.

**[M]** **cell_azimuth** is the weighted average of the azimuth angles of the pulse-composites within the WVC.

**[M]** **cell_incidence** is the weighted average of the incidence angles of the pulse-composites within the WVC.

**[M]** **data_format_type** valid value is `BINARY`.

**[M]** **EquatorCrossingTime** contains date and time in UTC format.

**[M]** **LongName** valid value is `QuikSCAT Merged Wind Vectors and Sigma0s`.

**[M]** **median_filter_method** valid values includes `Wind vector median filter` and `Wind vector median filter with DIR`.

**[M]** **nudging_method** valid values includes `AVN Forecast Field`.

**[M]** **num_sigma0_per_cell** maximum value is 4.

**[M]** **producer_agency** valid values includes `NOAA`.

**[M]** **producer_institution** valid values includes `NESDIS`.

**[M]** **rev_number** is a record element, not a global attribute as in the SWS_Sci. Data in the SWS_Sci are assigned to a rev based on the actual time of the measurement; data in the SWS_Met MGDR and SWS_Met BUFR are assigned to a rev based on the associated **wvc_row_time**. For more details see Section 5.2.

**[M]** **ShortName** valid value is `QSCATMGDR`.

**[M]** **wind_dir** for the selected index is replaced by the DIR solution.

**[M]** **wind_speed** for the selected index is replaced by the DIR solution.

## 3.2 Data Elements Added

There are no record elements added for the SWS_Met MGDR. There are several header elements added:

**[D]** **num_header_records** is the number of header records in the data set. The valid value is 1.

**[D]** **OrbitSemiMajorAxis** is the orbit semi-major axis.

**[D]** **OrbitEccentricity** is the orbit eccentricity.

**[D]** **OrbitInclination** is the orbit inclination.

**[D] OrbitNodalPeriod** is the orbit nodal period.

**[D] DataStartTime** is the minimum **wvc_row_time**.

**[D] DataEndTime** is the maximum **wvc_row_time**.

**[D] num_data_records** is the number of data records present. This count does not include the header record.

**[D] data_record_length** is the length of each data record. The valid value is 13252.

**[D] sigma0_composition_method** indicates that WVC-composites are given. The valid value is `Composite-composite/one measurement per beam`.

**[D] geophysical_model_function** is the name of the model function used in the wind retrieval. The valid values include `NSCAT-2`.

The elements containing the orbital parameters along with **EquatorCrossingLongitude** may be used to convert between latitude and longitude and WVC row and cell coordinate systems. This is described in the Science Algorithm Specifications [1], submodule Subtrack Binning, code section L2A.1.3.1.

## 3.3 File Name and Structure

The SWS_Met filename convention is "QS_NRTyyyydddhhmm.DAT", where yyyy indicates the year, ddd the julian day, hh the hour and mm the minute of the first data. Each file consists of one ASCII header record containing processing information, and a number of binary data records (Table 2). If exactly one rev is processed there would be 1624 data records. However, there may be an arbitrary number (0.25, 1.6, etc.) of revs represented by a single SWS_Met data set. Furthermore, if there is a data gap, WVC rows with no $\sigma^0$ measurements are not present in the data set. Both the header and data records are of fixed length, 13252 bytes, to facilitate direct-access reads in Fortran and IDL.

Table 2: File organization of the QuikSCAT SWS_Met data products.

| HEADER (13252 bytes) |
|---|
| Data Record 1 (13252 bytes) |
| Data Record 2 (13252 bytes) |
| ... |
| ... |
| Data Record 1702 (13252 bytes) |

### 3.4 Header Record Structure

The header record is organized in 80-character sub-records ending in `<CR><LF>`, so that the header information may be easily viewed in a standard terminal window. See Table 3 for an example of a header record. Many of the data elements in the header are described in detail in the Level 2B Software Interface Specification (SIS) [16].

### 3.5 Data Record Structure

The contents of the SWS_Met data record are listed in Table 4. Here "Type" denotes storage type, "N" is the number of bytes per value, "I" and "J" are the dimensions of the array, "Size" is the total size of the element and "Offset" is the number of bytes in the record before the element. Each data record contains the data for a cross-track row or strip of wind vector cells, centered on nadir. Wind vector data is in the first 3980 bytes of the record, followed by the $\sigma^0$ data, followed by the rain and brightness temperature information.

Storage is allowed in the data record for each of the four flavors. For ocean cells containing sufficient $\sigma^0$ data, up to four wind vector solutions (ambiguities) are given. The vectors are given in descending order of "likelihood" (goodness of fit to the model function), and the vector selected by the ambiguity removal algorithm is indicated by the entry in **wvc_selection**. The technique used to perform the ambiguity removal is described in the header. The default method is to use NWP wind field initialization, the vector median filter, and the direction interval retrieval (DIR) algorithm. When the DIR method is used, the selected ambiguity is replaced with the DIR solution. DIR spatially filters the directions of the chosen ambiguities, keeping within the directional intervals inferred during wind retrieval.

# 4 Reading SWS_Met MGDR Data Files

### 4.1 Reading the header

To view the header, simply print the first few lines as in "`head -n` *filename*".

To read the header from within a fortran program, open the file with `access='direct'` and `recl=MGDRSIZE`, where `MGDRSIZE =13252`. In addition define:

```
parameter (NUMHDRELE = MGDRSIZE/80)
character a(MGDRSIZE)
character*80 ahead(NUMHDRELE)
equivalence (a(1),ahead)
```

Now it is possible to read the first record (`read(..., rec=1, ...)`) into `a` and then scan the `ahead` array for any desired field, as in:

```
do i=1,NUMHDRELE
   ind = index(ahead(i),'OrbitInclination ')
```

Table 3: QuikSCAT SWS_Met data file header example.

```
num_header_records            = 1
LongName                      = QuikSCAT Merged Wind Vectors and Sigma0s
ShortName                     = QSCATMGDR
VersionID                     = 2.0
producer_agency               = NASA
producer_institution          = JPL
InstrumentShortName           = SeaWinds
PlatformLongName              = NASA Quick Scatterometer
project_id                    = QuikSCAT
data_format_type              = BINARY
GranulePointer                = QS_NRT20000280930.dat
InputPointer                  = QS_P1B20000280930
sis_id                        = 686-644-03A/2000-01-2
build_id                      = 2.3.1/2000-01-14
OperationMode                 = Wind Observation
ephemeris_type                = GPS
StartOrbitNumber              = 03174
StopOrbitNumber               = 03175
EquatorCrossingTime           = 2000-028T08:31:13.326
EquatorCrossingLongitude      = 295.7678
OrbitSemiMajorAxis            =  7189366
OrbitEccentricity             = 0.00099166
OrbitInclination              = 98.61891
OrbitNodalPeriod              = 6073.678
DataStartTime                 = 2000-028T09:27:59.995
DataEndTime                   = 2000-028T10:26:10.664
ProductionDateTime            = 2000-028T11:21:44.000
num_data_records              =   936
data_record_length            = 13252
sigma0_composition_method     = Composite-composite/one measurement per beam
sigma0_attenuation_method     = Attenuation Map
geophysical_model_function    = NSCAT-2
nudging_method                = AVN Forecast Field (1 deg/6 hr res.) ini
median_filter_method          = Wind vector median filter with DIR
rain_flag_algorithm1          = Multi-Parameter MLE/speed/dir/NBD algorithm
rain_flag_algorithm2          = Normalized Objective Function algorithm
rain_flag_algorithm3          =
rain_flag_alg1_threshold      = 0.085
rain_flag_alg2_threshold      = 45
rain_flag_alg3_threshold      =
spare_metadata_element        =
spare_metadata_element        =
```

⋮

Table 4: QuikSCAT SWS_Met data record definition.

| Variable | Definition | Type | N | I | J | Size | Offset | Scale | Units |
|---|---|---|---|---|---|---|---|---|---|
| **wvc_row_time** | UTC time tag | char | 24 | 1 | 1 | 24 | 0 | n/a | |
| **rev_number** | Revolution number for row | uint16 | 2 | 1 | 1 | 2 | 24 | 1 | |
| **wvc_row** | Row number (1-1624) within rev | int16 | 2 | 1 | 1 | 2 | 26 | 1 | |
| **wvc_lat** | Geodetic latitude of WVC | int16 | 2 | 76 | 1 | 152 | 28 | 0.01 | deg |
| **wvc_lon** | East longitude of WVC | uint16 | 2 | 76 | 1 | 152 | 180 | 0.01 | deg |
| **wvc_quality_flag** | Defined in L2B SIS | uint16 | 2 | 76 | 1 | 152 | 332 | 1 | |
| **model_speed** | NWP (nudge field vector) speed | int16 | 2 | 76 | 1 | 152 | 484 | 0.01 | m/s |
| **model_dir** | NWP (nudge field vector) dir | uint16 | 2 | 76 | 1 | 152 | 636 | 0.01 | deg |
| **num_ambigs** | Number of wind solutions | byte | 1 | 76 | 1 | 76 | 788 | 1 | |
| **wind_speed** | Surface wind speed (10m ref) | int16 | 2 | 4 | 76 | 608 | 864 | 0.01 | m/s |
| **wind_dir** | Surface wind direction | uint16 | 2 | 4 | 76 | 608 | 1472 | 0.01 | deg |
| **wind_speed_err** | Estimated speed uncertainty | int16 | 2 | 4 | 76 | 608 | 2080 | 0.01 | m/s |
| **wind_dir_err** | Estimated direction uncertainty | int16 | 2 | 4 | 76 | 608 | 2688 | 0.01 | deg |
| **max_likelihood_est** | Relative MLE likelihood | int16 | 2 | 4 | 76 | 608 | 3296 | 0.001 | |
| **wvc_selection** | Index of selected wind vector | byte | 1 | 76 | 1 | 76 | 3904 | 1 | |
| **num_sigma0_per_cell** | Number of sigma0s (nom. 4) | byte | 1 | 76 | 1 | 76 | 3980 | 1 | |
| **cell_lat** | Sigma0 cell latitudes | int16 | 2 | 4 | 76 | 608 | 4056 | 0.01 | deg |
| **cell_lon** | Sigma0 cell longitudes | uint16 | 2 | 4 | 76 | 608 | 4664 | 0.01 | deg |
| **cell_azimuth** | Sigma0 cell relative azimuths | uint16 | 2 | 4 | 76 | 608 | 5272 | 0.01 | deg |
| **cell_incidence** | Sigma0 cell incidence angles | int16 | 2 | 4 | 76 | 608 | 5880 | 0.01 | deg |
| **sigma0** | Normalized radar backscatter | int16 | 2 | 4 | 76 | 608 | 6488 | 0.01 | dB |
| **kp_alpha** | Variance coefficient | int16 | 2 | 4 | 76 | 608 | 7096 | 0.001 | |
| **kp_beta** | Variance coefficient | int16 | 2 | 4 | 76 | 608 | 7704 | 1.00E-08 | |
| **kp_gamma** | Variance coefficient | float | 4 | 4 | 76 | 1216 | 8312 | 1 | |
| **sigma0_attn_map** | Rain-free nadir attenuation | int16 | 2 | 4 | 76 | 608 | 9528 | 0.01 | dB |
| **sigma0_qual_flag** | Defined in L2A SIS | uint16 | 2 | 4 | 76 | 608 | 10136 | 1 | |
| **sigma0_mode_flag** | Defined in L2A SIS | uint16 | 2 | 4 | 76 | 608 | 10744 | 1 | |
| **surface_flag** | Defined in L2A SIS | uint16 | 2 | 4 | 76 | 608 | 11352 | 1 | |
| **mp_rain_probability** | Multi-parameter rain probability | int16 | 2 | 76 | 1 | 152 | 11960 | 0.001 | |
| **nof_rain_index** | Normalized objective function index | byte | 1 | 76 | 1 | 76 | 12112 | 1 | |
| **tb_mean_h** | Mean Hpol brighness temp. | uint16 | 2 | 76 | 1 | 152 | 12188 | 0.1 | K |
| **tb_mean_v** | Mean Vpol brighness temp. | uint16 | 2 | 76 | 1 | 152 | 12340 | 0.1 | K |
| **tb_stddev_h** | Standard deviation of Hpol Tb | uint16 | 2 | 76 | 1 | 152 | 12492 | 0.1 | K |
| **tb_stddev_v** | Standard deviation of Vpol Tb | uint16 | 2 | 76 | 1 | 152 | 12644 | 0.1 | K |
| **num_tb_h** | Number of Hpol Tb's in average | byte | 1 | 76 | 1 | 76 | 12796 | 1 | |
| **num_tb_v** | Number of Vpol Tb's in average | byte | 1 | 76 | 1 | 76 | 12872 | 1 | |
| **tb_rain_rate** | Rain rate estimated from Tb's | uint16 | 2 | 76 | 1 | 152 | 12948 | 0.01 | mm/hr |
| **tb_attenuation** | Attenuation estimated from Tb's | uint16 | 2 | 76 | 1 | 152 | 13100 | 0.01 | dB |
| **TOTAL RECORD** | | | | | | | **13252** | | |

```
          if (ind.gt.0) then
             nele = i
             goto 142
          endif
       end do
       write(*,*) 'WARNING: Could not find OrbitInclination',
      & ' in MGDR ahead, using default value (98.6).'
       goto 151
 142   continue
       ind = index(ahead(nele),'= ')
       read(ahead(nele)(ind+2:80),*) inclination
 151   continue
```

## 4.2 Reading the records

The records may be read with direct access reads in fortran into a as defined above, but now equivalenced to the MGDR data structure as:

```
       integer       BUFD,BUFW,AMBIGS
       parameter     (BUFD   = 4,
      $               BUFW   = 76,
      $               AMBIGS = 4)

       CHARACTER*24 Row_Time                ! mean time tag for WVC row

       REAL*4
      $     Coeff_C(BUFD,BUFW)              ! Kp "gamma" coefficient

       INTEGER*2
      $     Rev,                            ! rev number
      $     WVC_Row,                        ! WV row index (along-track)
      $     WVC_lat(BUFW),                  ! WVC latitude
      $     WVC_lon(BUFW),                  ! WVC longitude
      $     WVCqual_flag(BUFW),             ! WVC data quality flag
      $     Modelspd(BUFW),
      $     Modeldir(BUFW),
      $     Windspd(AMBIGS,BUFW),           ! wind speed sol'ns 1-AMBIGS
      $     Winddir(AMBIGS,BUFW),           ! wind direction 1-AMBIGS
      $     Errspd(AMBIGS,BUFW),            ! wind speed error 1-AMBIGS
      $     Errdir(AMBIGS,BUFW),            ! error in direction 1-AMBIGS
      $     MLE_like(AMBIGS,BUFW),          ! rel. sol'n probability 1-AMBIGS
      $     Cen_Lat(BUFD,BUFW),             ! sigma0 cell latitudes
      $     Cen_Lon(BUFD,BUFW),             ! sigma0 cell longitudes
```

```
     $     Cell_Azimuth(BUFD,BUFW),        ! cell azimuths of sigma0’s
     $     Incidence_Angle(BUFD,BUFW),     ! incidence angles of sigma0’s
     $     Sigma0(BUFD,BUFW),              ! sigma0 values
     $     Coeff_A(BUFD,BUFW),             ! Kp "alpha" coefficient
     $     Coeff_B(BUFD,BUFW),             ! Kp "beta" coefficient
     $     Mean_Atm_Atten(BUFD,BUFW),      ! attenuation correction
     $     Sigma0_Quality_Flag(BUFD,BUFW),
     $     Sigma0_Mode_Flag(BUFD,BUFW),
     $     Surface_Flag(BUFD,BUFW),
     $     MP_rain_index(BUFW),            ! multi-param rain probability
     $     Tb_mean_H(BUFW),
     $     Tb_mean_V(BUFW),
     $     Tb_stddev_H(BUFW),
     $     Tb_stddev_V(BUFW),
     $     Tb_rain_rate(BUFW),
     $     Tb_attenuation(BUFW)

      BYTE
     $     Nambigs(BUFW),                  ! number of ambiguities
     $     WVC_select(BUFW),               ! selected ambiguity (checkmark)
     $     NumSigma0(BUFW),                ! number of sigma0 per cell
     $     NOF_rain_index(BUFW),           ! NOF rain index
     $     Num_Tb_H(BUFW),
     $     Num_Tb_V(BUFW)
c
      COMMON /MGDR_OUT/
     $     Row_Time, Rev, WVC_Row,
     $     WVC_Lat, WVC_Lon, WVCqual_flag,
     $     Modelspd,Modeldir, Nambigs,
     $     Windspd, Winddir, Errspd, Errdir, Mle_like,
     $     WVC_select,
     $     NumSigma0,
     $     Cen_Lat, Cen_Lon,
     $     Cell_Azimuth, Incidence_Angle,
     $     Sigma0, Coeff_A, Coeff_B, Coeff_C,
     $     Mean_Atm_Atten,
     $     Sigma0_Quality_Flag, Sigma0_Mode_Flag,
     $     Surface_Flag,
     $     MP_rain_index, NOF_rain_index, Tb_mean_H,
     $     Tb_mean_V, Tb_stddev_H, Tb_stddev_V,
     $     Num_Tb_H, Num_Tb_V, Tb_rain_rate,
     $     Tb_attenuation
```

```
parameter (MGDRSIZE = 28 + BUFW*(30 + 26*BUFD + 10*AMBIGS))
                    ! = 13252 for bufd=4

character a(MGDRSIZE)

equivalence (a(1),Row_Time)
```

After each record is read, type conversion, scaling and offsets must be applied as in:

```
mgdr_WVC_Lon(j) = usignint2(WVC_Lon(j)) * 0.01
mgdr_NOF_rain_index(j) = usignint1(NOF_rain_index(j))
```

Here `mgdr_WVC_Lon(j)` is a `REAL` variable, and `mgdr_NOF_rain_index(j)` is an `INTEGER` variable.

The fortran functions referenced above are used to convert the contents of one or two byte integers, which contain unsigned values, to four byte integers. These functions are implemented as:

```
integer function usignint2(input)
integer*2 input
usignint2=input
if(usignint2 .lt. 0) usignint2=usignint2+65536
return
end

integer function usignint1(input)
byte input
usignint1=input
if(usignint1 .lt. 0) usignint1=usignint1+256
return
end
```

This conversion is a common source of confusion and and arises from the fact that several key quantities in the SWS_Met MGDR data products are stored as unsigned integers. Users who commonly program in C have no problem with this, since the C language recognizes unsigned data types. However, Fortran and IDL, in particular, do not have unsigned types, which can lead to some degree of confusion in reading the data. We have used unsigned types (2-byte and 1-byte integers) for storing some of the data in order to maximize the range of significant figures without resorting to the use of offsets. For example, the **wvc_lon** (wind vector cell longitude) can range from 0° to 360°; when scaled by 100 for storage as 2-byte integers, all values greater than 327.67 degrees $0.01 \times (2^{15} - 1)$ will appear in Fortran and IDL as negative numbers, since the sign bit (bit 15) is set. Use of the above two conversion routines avoids these problems.

### 4.3 Handling Unsigned Integers in Fortran and IDL

A simple way to handle unsigned integers in Fortran and IDL is to copy the stored value into a long (4-byte) integer, test the sign of the resulting copy, and, if the copy is negative, add either $65536 = 2^{16}$ (for 2-byte stored values) or $256 = 2^8$ (for 1-byte stored values). Then the modified 4-byte copy can be scaled to the desired floating point data value. For example, if the actual value of the **wvc_lon** for some vector is equal to 345.25 degrees, the unsigned integer value as stored in the file is 34525 after scaling by 100. This will appear in Fortran and IDL as -31011, because the sign bit is set. After copying this to a 4-byte real variable, scaling and checking the sign, we add 655.36 ($-310.11 + 655.36 = 3452.5$) to recover the original direction value (345.25 degrees). A code fragment to accomplish this is:

```
       mgdr_WVC_Lon(j) = WVC_Lon(j)*0.01
       if (mgdr_WVC_Lon(j) .lt. 0.)
     $    mgdr_WVC_Lon(j) = mgdr_WVC_Lon(j) + 655.36
```

## 5 Using SeaWinds Data

When using SWS_Met data files, it should be remembered that WVC 1-38 always represent data taken on the left side of the spacecraft and WVC 39-76 include data from the right side of the spacecraft. Also the wind ambiguities are always ordered by descending likelihood, and the $\sigma^0$ values are arbitrarily ordered.

### 5.1 Missing Values and Flags

Zero is a valid value for most SeaWinds data elements. The SWS_Sci and SWS_Met MGDR set missing or null values to zero. To determine which elements are missing, one must use information in various flags and key data elements as described in Section "1.6.8 Null Values" in each of the SIS [14, 15, 16]. This information is summarized below. The translation to SWS_Met BUFR uses this information to determine missing elements. In BUFR, missing values are set to the special value, called the missing data indicator (MDI).

Flags are all initially set to a value of 1 (turned on). Each flag is cleared to a value of 0 (turned off) when and if the particular test is passed. Thus when a cell is flagged because winds were not retrieved (bit 9 of **wvc_quality_flag** is set), then high and low wind speed flag processing is bypassed, and bits 10 and 11 remain set. This approach is used for all flags in the SWS_Sci. In the SWS_Met data sets there is one exception: an ice flag is cleared if land is present. This effects bit 8 of **wvc_quality_flag** and bit 1 of **surface_flag**.

The order in which individual flags are processed is not always obvious. For most usage, this does not matter, since only data which has passed all relevant quality control tests will be used. If data of lesser quality is to be used, then detailed knowledge of the ordering of the quality control procedures is required. See Section "1.6.7 Bit Flag Conventions" in each of the SIS [14, 15, 16]. The following sub-sections describes how to use the flags.

## 5.2 Data Overlap and Implications

Each SWS_Sci file corresponds to a single revolution or rev, defined as starting and ending at the southernmost latitude of the orbit (i.e., over Antarctica). [NOTE that orbits start at the ascending equator crossing and revs start closest to the South Pole.] As noted earlier, each WVC row corresponds to a single cross-track cut of the SeaWinds instrument measurement swath. Each SWS_Met WVC is 25 *km* square, so 1624 WVC rows are adequate to cover one complete circumference of the earth.

Data is processed in real-time in batches. Such a batch might be obtained from a single downlink. For this reason, a batch of data is called a data pass since a downlink is communicated in a single pass of the satellite overhead. However a data pass is really an arbitrary batch of data corresponding to a contiguous portion of the QuikSCAT telemetry stream. Data passes may vary in size due to variations in communication times and processing schedules. A data pass may correspond to one or more portions of one or more orbits and to a portion of a downlink, exactly one downlink or multiple downlinks. The current nominal procedure is to obtain all data for the last 110 minutes every 100 minutes in a single downlink. This corresponds to one orbit's worth of data plus a ten minute overlap. The recorded data for the downlink start and end near the north pole, and are divided into two data passes for more timely processing. That is, data collected for ascending and descending tracks are processed independently. Note that in this nominal case, there will be no winds retrieved near the edges of the data passes, where repeating WVC rows will occur. If a downlink is missed, and more than one rev is downlinked subsequently, then the on-time data is processed first and the late data is processed last.

The SWS_Met MGDR and SWS_Met BUFR are record oriented and each record corresponds to a single WVC row. However, due to data overlap, a WVC row may be associated with multiple records, and some care must be taken to choose the most complete record. For the SWS_Sci there are no duplicate $\sigma^0$ values, but $\sigma^0$ values are divided strictly by rev, and some WVC rows near the south pole will have $\sigma^0$ values in two files, with foreward flavored $\sigma^0$ one rev behind the aft flavored $\sigma^0$. In the nominal case, even in real time, this will not affect WVC rows containing wind retrievals. The details are described in the following paragraphs.

The input to the SWS_Met and science processing algorithms is time ordered and defined by time boundaries, and the output is in spatial order and defined by spatial boundaries. To ensure that input and output contain the same data, the processing algorithms must consider the acquisition pattern of the SeaWinds instrument's rotating antenna. For example, for the science processing, as the spacecraft approaches and passes a rev boundary, the SeaWinds instrument acquires data on either side of that boundary. Thus, the SWS_Sci must include WVC rows which extend beyond the 1624 rows which comprise one complete earth circumference. To cover those $\sigma^0$ measurements which lie beyond the boundaries of the rev, the SWS_Sci include up to 39 additional WVC rows before the start and after the end of each rev. These additional WVC rows cover 975 *km* at each end of the rev. Thus, the nominal SWS_Sci contain 1702 WVC rows and WVC rows 1-39 and 1586-1624 occur twice. Since the rev boundary is close to the South Pole, no wind retrievals are affected.

For SWS_Met processing, data passes are normally processed in time order. Each data pass contains all available data observed within an arbitrary time interval. Data corresponding to at least the last 39 rows of WVCs from one data pass will be repeated in the next data pass. The current nominal procedure is to repeat ten minutes of telemetry in two successive passes.

In an application when multiple files are concatenated, or where many BUFR records are collected into a data base, this will result in WVC rows repeating. In the nominal case the WVC rows which repeat have no winds—if the application uses only wind data, no special action is required. However if the overlap region occurs where wind retrieval is possible, or if the application makes use of $\sigma^0$ values over land or ice, then one of each pair of WVC rows must be selected for further processing.

First repeating WVC row records must be detected. For repeating WVC row records the values of **wvc_row_time** will be close to identical. A better approach is to match **wvc_row** and **rev_number**, since these should be unique. (This is in contrast to the SWS_Sci, where there are multiple WVC row records with the same value of **wvc_row** for a single rev.)

For a given WVC row that repeats, the data values may be identical or different, depending on whether additional $\sigma^0$ values are present in one of the WVC row records. In this case, we eliminate the record which has fewer $\sigma^0$ values. Even when all data values agree, the ambiguity selection might be different.

In all cases the higher quality data is expected be be furthest from the edge of the data pass. This is easily done when concatenating MGDR files, since the data in each file are ordered from the beginning to the ending edge of the data pass.

## 5.3 Ocean Wind Vector Data

The ocean wind vector data are contained in data elements

**wind_speed**;
**wind_speed_err**;
**wind_dir**;
**wind_dir_err**; and
**max_likelihood_est**.

Use **num_ambigs** to determine the number of non-missing wind ambiguities. If **num_ambigs** is $n$, then the first $n$ locations for each wind data element will contain data. If the $\sigma^0$ data are not of sufficient quality or over land or ice, $n = 0$, all wind data elements, including **wvc_selection**, will be missing, and bit 9 of **wvc_quality_flag** will be set. Note that zero is not a valid value for **wind_speed_err** and **wind_dir_err**, and is an alternative indication that the associated wind ambiguity is missing.

Several other data quality indicators are also present in **wvc_quality_flag**, including whether there are not enough good $\sigma^0$ values for wind retrieval (bit 0); whether there is not enough azimuthal diversity for wind retrieval (bit 1); whether some land is within the WVC (bit 7); whether some ice is within the WVC (bit 8); whether the retrieved wind speed is $> 30\ m/s$ (bit 10); and whether the retrieved wind speed is $< 3\ m/s$ (bit 11). Currently bit 12 through bit 15 are used to store experimental rain flags. For more details see the Level 2B SIS.

It is important to note that all wind directions in the SWS_Sci and SWS_Met MGDR are given in the "oceanographic" convention, i.e. wind flowing toward the North is defined as 0 degrees, with positive angles increasing in the clockwise direction. That is, the vector points in the direction of flow. To convert the vectors from speed and direction denoted $(U, \phi)$ to zonal and meridional components $(u, v)$, use:

$$u = U \sin \phi,$$
$$v = U \cos \phi.$$

## 5.4 Precipitation information

Experimental precipitation information is included in data elements

**mp_rain_probability**;
**nof_rain_index**;
**tb_rain_rate**; and
**tb_attenuation**.

The **mp_rain_probability** and **nof_rain_index** are described in the Level 2B SIS. Because these elements depend on the $\sigma^0$ values, separate tables and thresholds were developed for the WVC-composites.

Currently **tb_rain_rate** and **tb_attenuation** are placeholders.

## 5.5 Brightness temperature information

Experimental brightness temperature information is included in data elements

**tb_mean_h**;
**tb_mean_v**;
**tb_stddev_h**;
**tb_stddev_v**;
**num_tb_h**; and
**num_tb_v**.

Brightness temperatures are deduced from the noise measurement associated with each pulse. The accuracy of the individual brightness temperatures is poor, so the mean over each WVC is calculated, separately for the inner and outer beams. For potential quality control procedures, the standard deviation within the WVC and the number of individual measurements used in the averaging are included as well.

Currently all these elements are placeholders. They will be defined in later versions of the SIS.

## 5.6 Collocated $\sigma^0$ Data

The $\sigma^0$ data are contained in

**cell_latitude**;
**cell_longitude**;
**sigma0_atten_map**;
**cell_azimuth**;
**cell_incidence**;
**polarization**;
**sigma0**;
**kp_alpha**;
**kp_beta**;
**kp_gamma**;
**sigma0_quality_flag**;
**sigma0_mode_flag**; and
**surface_flag**.

These are the elements below the line in Table 4. The total number of WVC-composite $\sigma^0$ values in a WVC is given by **num_sigma0_per_cell**. When a $\sigma^0$ value is missing, all associated variables are also missing. Note that zero is not a valid value for **cell_incidence**, and indicates that the associated $\sigma^0$ value is missing.

There are three bit flag data elements relevant to the use of the $\sigma^0$ data. These are the **sigma0_mode_flag**, **sigma0_quality_flag**, and **surface_flag**. In general, all three should be examined when using $\sigma^0$ values.

The **sigma0_mode_flag** indicates the instrument mode and status associated with the $\sigma^0$ value. Bits 2 and 3 of **sigma0_mode_flag** may be used to verify the "flavor" of each value; in particular, bit 2 of **sigma0_mode_flag** may be used to determine which antenna beam corresponds to a particular $\sigma^0$ value. The inner antenna beam is always horizontally polarized and the outer antenna beam is always vertically polarized. This must be consistent with **polarization**. In addition, for usable geophysical data, bits 0, 1, 4, and 5 must be zero.

If **sigma0_quality_flag** bit 0 is zero, then the associated individual $\sigma^0$ value is usable from the engineering point of view. If bit 0 is set to one, then bits 1 and 3–9 may be helpful in identifying the reason why the value is not considered usable. NOTE that if the $\sigma^0$ value is considered usable, that does not necessarily imply either that the measurement was used for wind retrieval or is even usable for wind retrieval. A usable value may be over land or ice.

Bit 2 of the **sigma0_quality_flag**, denoted $s$ here, indicates whether the normal (ratio) space $\sigma^0$ is negative. Any use of the $\sigma^0$ values must take into account this bit flag. The $\sigma^0$ measurements are provided in $dB$. To properly use the data the following conversion must be used:

$$\sigma^0[\text{ratio}] = (-1)^s 10^{(\sigma^0[dB]/10)}.$$

Negative $\sigma^0$ observations are indicative of very light winds. However, the applicability of the attenuation correction and $K_p$ values are uncertain in this situation.

The **sigma0** values are the observed top of the atmosphere values. These values should be corrected for atmospheric effects. The **sigma0_atten_map** values are the rain-free two-way nadir attenuation corrections to be applied to the $\sigma^0$ data based on the monthly Wentz-SSM/I climatology. The value does not include the $\sec\theta$ correction, where $\theta$ is the incidence angle of the measurement. The basic relationship is that

$$\sigma^0{}_T[\text{ratio}] = \tau^2 \sigma^0{}_S[\text{ratio}],$$

where subscripts $T$ and $S$ denote top of the atmosphere and surface, respectively and $\tau$ is the one-way transmittance, itself given by,

$$\tau = \exp(-\alpha \sec\theta),$$

where $\alpha$ is the atmospheric opacity in the vertical, measured in *napers*. Converting to decibels and solving for $\sigma^0$ at the surface gives,

$$\sigma^0{}_S[dB] = \sigma^0{}_T[dB] + A \sec\theta.$$

That is, to remove the atmospheric effect, $A$, the **sigma0_atten_map** multiplied by $\sec\theta$ is added in $dB$ space to the value of **sigma0**. Here

$$A = 10\log(\tau_0^{-2}) = 20log(e)\alpha,$$

where $\tau_0 = e^{-\alpha}$ is the one-way transmittance at nadir.

In the case of negative $\sigma^0$, ($s = 1$), the atmospheric correction described in the previous paragraph does not apply. One could replace $\sigma^0$ by $|\sigma^0|$ everywhere in the above development and obtain the same answer for these cases as well. However, when $\sigma^0$ is negative the basic relationship describing attenuation above, which neglects noise, does not hold because noise is in fact dominating the signal. [***TBD: Currently, when $\sigma^0$ is negative, the SeaWinds data processing algorithms add the attenuation in $dB$ space, but this is expected to change shortly to subtracting the attenuation in $dB$ space, while leaving the sign bit set. With this approach a negative $\sigma^0$ is corrected to a less negative $\sigma^0$. Such a correction is at least in the right direction, but one might argue that it is better to make no correction in this case.***]

The SWS_Met data set includes $\sigma^0$ data for all surface types. The surface type may be inferred from **surface_flag**, bit 0 and bit 1. If bit 0 is set to one, then land is present; if bit 1 is set to one then ice is present and no land is present. NOTE that the surface type indicators do not allow one to infer if the surface is entirely land, or entirely ice, or some mixture. One can only infer either some land is present; or that some ice is present and no land is present; or that only water is present. If bit 10 is set to one than an ice map was not available and no ice quality control was performed. In this case ice might be present, but bit 1 will be cleared to zero. Finally bit 11 of **surface_flag** should always be cleared to zero, indicating that an attenuation map was available.

### 5.7 $K_p$ Modeling

The **max_likelihood_est** is the value of the objective function which is maximized, divided by the number of $\sigma^0$ WVC-composites used. The objective function is the negative of the sum of squared differences between observed and modeled $\sigma^0$ values, where each squared difference is normalized by its expected variance, $\varepsilon^2$.

Three coefficients, denoted here as $\alpha$, $\beta$ and $\gamma$, are used to calculate $\varepsilon^2$, according to

$$\varepsilon^2 = [\alpha(1 + K_{pm}) - 1](\sigma^0)^2 + \beta\sigma^0 + \gamma.$$

The values of $\alpha$, $\beta$, and $\gamma$ are stored in data elements **kp_alpha**, **kp_beta**, and **kp_gamma**.

Together the coefficients $\alpha$, $\beta$ and $\gamma$ represent the effect of $K_{pc}$, the communication noise, and $K_{pr}$, the "radar equation" noise due to various geometrical and other instrument uncertainties. Also $K_{pm}$ accounts for errors in the formulation of the model function. The value of $\sigma^0$ used here should be the modeled value. That is, during wind retrieval, it is the estimate of $\sigma^0$ based on the current estimate of the wind.

This formula is really the same as that used for NSCAT, but isolates $K_{pm}$. Currently, $K_{pm}$ is a constant but is implemented as a table with the same dimensions as the model function table, and is in fact combined with the model function in the same file. This allows $K_{pm}$ to depend on wind speed, relative wind direction, incidence angle and polarization. We expect that $K_{pm}$ will be refined at some future time.

Note that since the noise estimate increases as the amount of data decreases, WVC-composites based on the smallest number of slices will generally have large noise estimates.

## 6 Points of Contact

Issues relating to data distribution and data processing, the scientific background and algorithms used, or this document should be brought to the attention of the appropriate personnel. Specific points of contact are given below. The preferred method of communication is e-mail.

- Real-time data distribution and processing issues should be referred to NOAA / NESDIS:

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| e-mail: | R.Scott.Dunbar@jpl.nasa.gov |
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- Corrections and updates to this User's Guide should be referred to:

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# 7 Acknowledgments

Thanks to David Long (BYU) for several of the figures. Thanks to many of our colleagues who provided useful comments and suggestions.

This work is supported by the QuikSCAT project.

# 8 References

Many of the newer JPL reports, including the Software Interface Specifications [14, 15, 16], can be found at:

- `ftp://podaac.jpl.nasa.gov/pub/ocean_wind/quikscat/doc/`
- `http://podaac.jpl.nasa.gov/quikscat/`

In addition [4, 5, 2] contain interesting background information.

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# 9 List of Acronyms

**ADCS** TBD

**ASCII** American Standard Code for Information Interchange

**BUFR** Binary Universal Form for the Representation of Meteorological Data

**BYU** Brigham Young University

**C/A** TBD

**CSC** Computer Sciences Corp.

**dB** Decibels

**ERS-1** European Remote-sensing Satellite 1

**FFT** fast Fourier transform

**GHz** Gigahertz

**GPS** Global Positioning System

**HDF** Hierarchical Data Format

**IDL** Interactive Data Language

**IRU** TBD

**JPL** Jet Propulsion Laboratory

**Kbps** kilobits per second

**Mbps** megabits per second

**MDI** missing data indicator

**MGDR** Merged Geophysical Data Record

**NASA** National Aeronautics and Space Administration

**NESDIS** National Environmental Satellite and Data Information Services

**NOAA** National Oceanic and Atmospheric Administration

**NSCAT** NASA Scatterometer

**NWP** Numerical Weather Prediction

**P/L** TBD

**PDT** Pacific Daylight Time

**PO.DAAC** Physical Oceanography Distributed Active Archive Center

**QuikSCAT** NASA Quick Scatterometer

**SAS** SeaWinds Antenna Subsystem

**SIS** Software Interface Specification

**SeaWinds** SeaWinds

**SWS_Met** SWS Real-Time Data Product

**SWS_Sci** SWS Science Data Product

**TBD** to be determined

**UTC** Coordinated Universal Time

**WVC** Wind Vector Cell