SeaWinds Scatterometer Real-Time BUFR Geophysical Data Product

User's Guide

Version 2.2.0

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Preface

This is a preliminary user's guide for the SeaWinds Real-Time BUFR Data Product (SWS_Met BUFR). 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 [2], the Science Data Product User's Manual [14], and the Software Interface Specifications [15, 16, 17], 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`.

Contents

1 Overview of SeaWinds Data Products

This document describes the SeaWinds Real-Time BUFR Data Product (SWS_Met BUFR). There are two other formats for SeaWinds data. These are the SeaWinds Science Data Product (SWS_Sci) [14], and the SeaWinds Real-Time MGDR Data Product (SWS_Met MGDR) [8]. 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 σ^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 σ^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 σ^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 (σ^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 [2] except that the SWS_Met data processing algorithms use WVC-composites, instead of pulses (*aka* eggs) or pulse-composites, of σ^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) [17]. Similarly detailed definitions of the σ^0 data elements are given by the Level 2A SIS [16]. Differences between the SIS and the SWS_Met BUFR are described in Sections 3.1 and 3.2.

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 σ^0 measurement. Variations in spacecraft attitude and the local curvature of the earth will cause very few σ^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 σ^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 BUFR bit numbering convention.

Fixed ordering is used to store the σ^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 and by the BUFR descriptor number in this format: **wvc_quality_flag** [021109].

Note that much of the material in section 2 is covered in greater detail in the Science Data Product User's Manual [14].

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 [12, 4]. 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

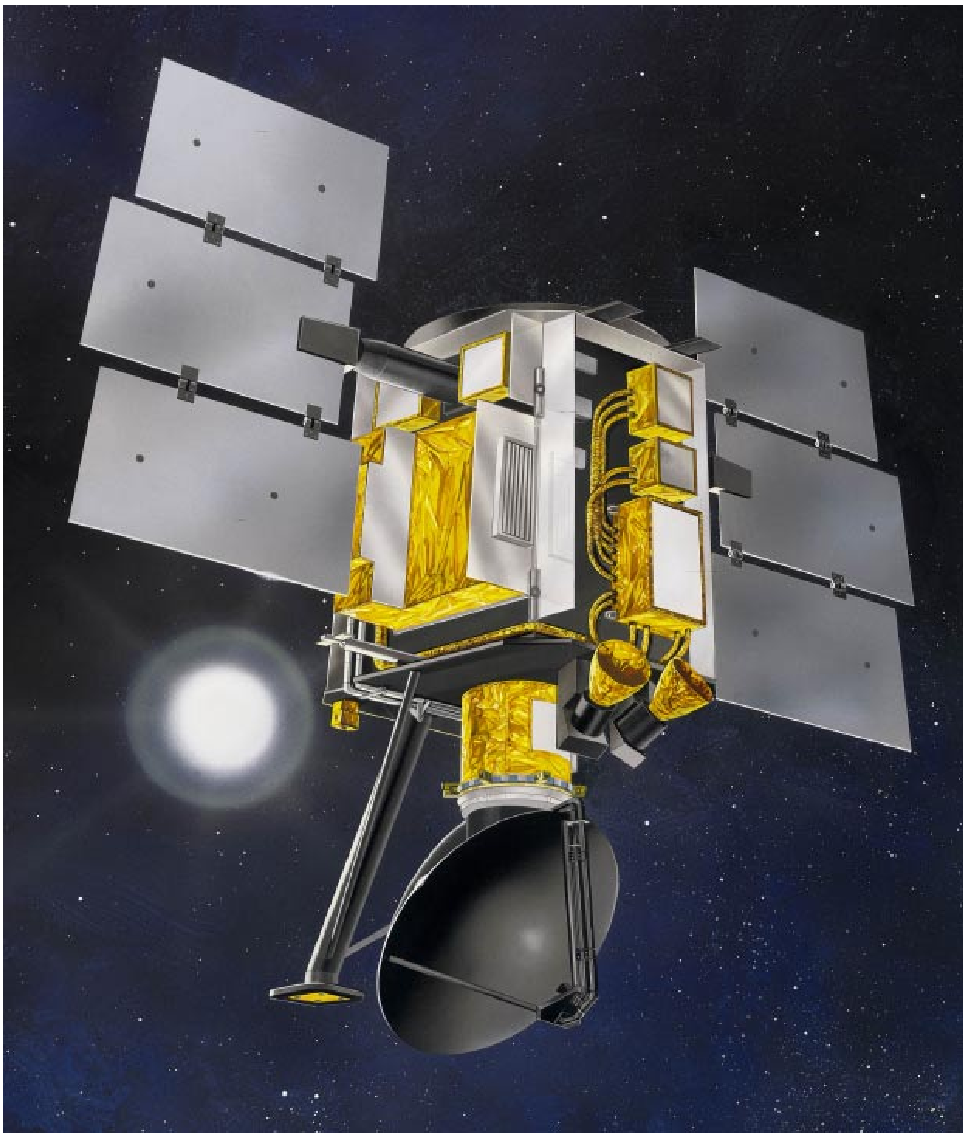

Figure 1: Artists depiction of SeaWinds on QuikSCAT.

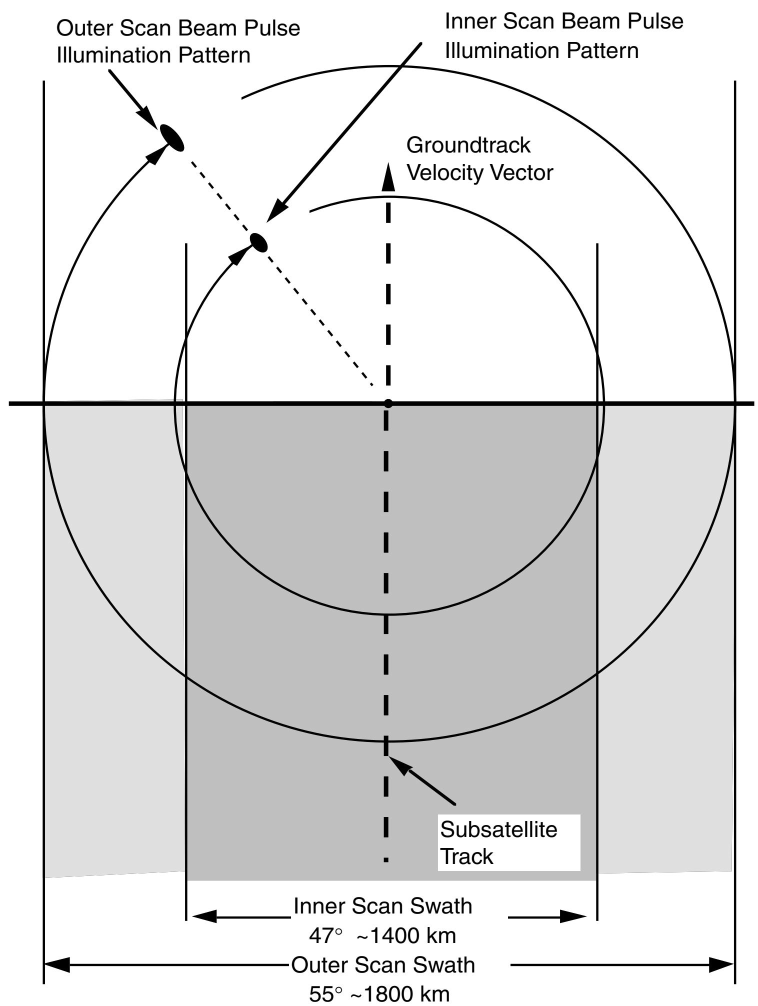

Figure 2: The SeaWinds swath.

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 (σ^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 σ^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 [7, 18] for a given set of σ^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 [13].

The wind retrieval processing for the SWS_Met is identical to that used for the SWS_Sci, except that the number of σ^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 σ^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 σ^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 σ^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 σ^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

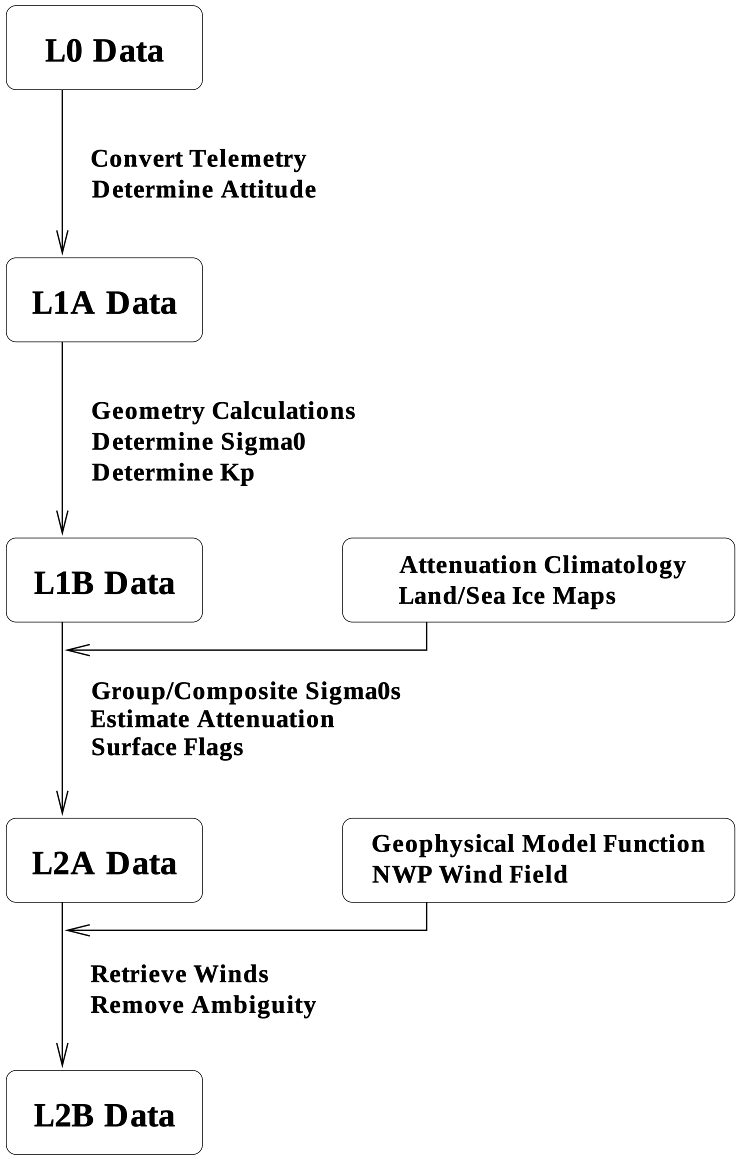

Figure 3: Data flow for SWS_Met data processing.

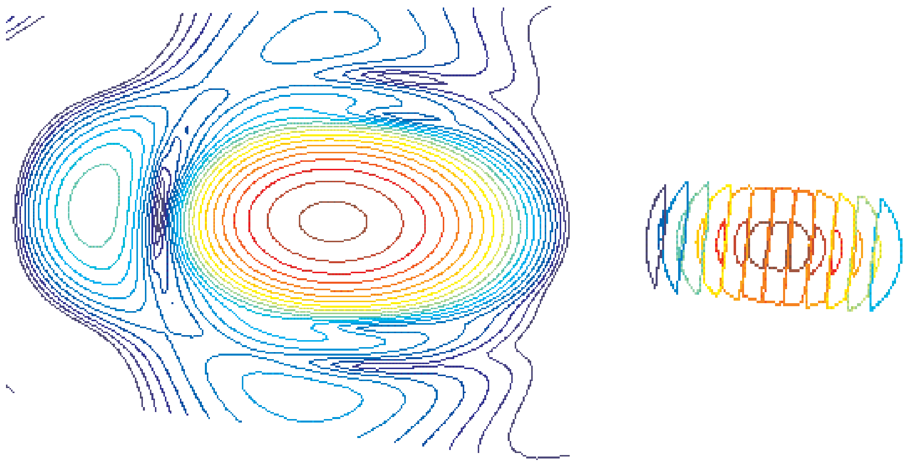

Figure 4: A pulse and its slices. The antenna response pattern for a single pulse is plotted with a contour interval of 1 dB on the left. The corresponding slices are shown on the right at the same scale. Here the contour interval is 3 dB, and only one or two most significant contours are shown. The outer or guard slices are used only to monitor the noise characteristics of the instrument. Up to eight inner slices are used to estimate σ^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 [11]. For instance, images generated from earlier scatterometer data have demonstrated the ability to discriminate tropical vegetation types [10], and have been useful in polar ice studies [9]. If the normalized radar cross section σ^0 in decibels is expressed in the form

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

where θ 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

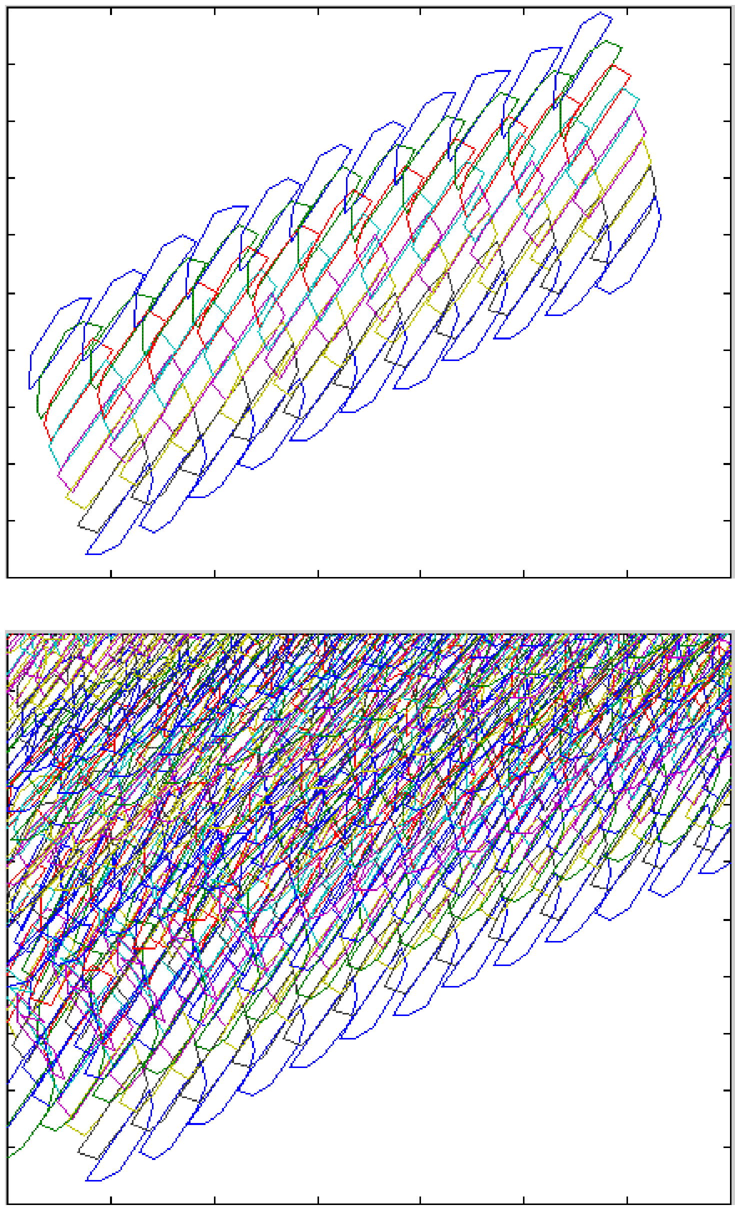

Figure 5: Slices simulated for the foreward inner beam for (top) a few pulses on a single scan line and (bottom) many pulses starting from the few shown above. The height of each panel corresponds to one degree of latitude or approximately 100 km. The slices are $\sim 25 \times 37$ km.

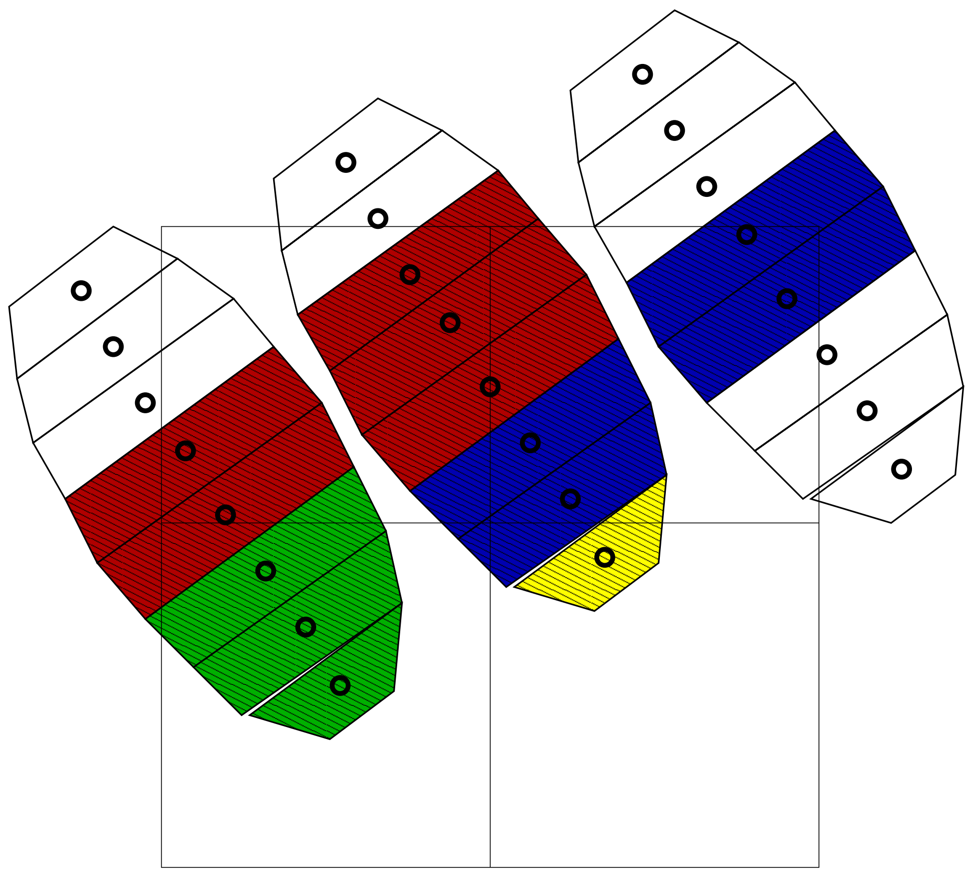

Figure 6: The slices for three pulses of a single flavor are shown along with four WVCs. The slices are shaded differently depending on which WVC contains the slice centroid. Slices with centroids outside the four WVCs are not shaded. All slices with the same shading contribute to the WVC-composite associated 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 σ^0 data over land and ice surfaces, as well as ocean, to help monitor these geographical areas.

3 Data Content and Format

The σ^0 data are colocated and organized into WVCs. Wind ambiguities are retrieved for each WVC with sufficient σ^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 σ^0 and wind data for a given cross-track row or strip of WVCs. WVC rows with no σ^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 σ^0 data in the record is the UTC time tag (**wvc_row_time** [004001/6]), 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**, **D**, **T**, **C**, and **A** are used to label list items in Sections 3.1 and 3.2, and to identify data elements in the tables of Section 3.4. **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). **T** indicates that a data element value is *translated* from the SWS_Met MGDR value, **C** indicates that a data element is not present in the SWS_Met MGDR but is *calculated* from information in the SWS_Met MGDR, and **A** that it is *assigned* a constant value (possibly on the basis of **build_id** [025060]).

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 for any data element names not defined in the SIS.

All record elements associated with σ^0 values are modified in the sense that the elements are WVC-composites instead of pulse-composites. As with the σ^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 σ^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 [2]. NOTE that (both pulse and WVC) compositing ignores surface type. Nothing special is done when combining σ^0 values for composites straddling a land/sea or ice/sea boundary. These composites should not be used for wind retrieval. (Use **surface_flag** [008018] to check for land or ice.)

In using the SIS definitions for the SWS_Met MGDR, some SIS definitions require minor modifications, but only those affecting the SWS_Met BUFR are listed here:

[M] **build_id** [025060] identifies the version of the SWS_Met software.

[M] **cell_azimuth** [002112] is the weighted average of the azimuth angles of the pulse-composites within the WVC.

[M] **cell_incidence** [002111] is the weighted average of the incidence angles of the pulse-composites within the WVC.

[M] **num_sigma0_per_cell** [021103] maximum value is 4.

[M] **rev_number** [005040] 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** [004001/6]. For more details see Section 5.2.

[M] **wind_dir** [011011] for the selected index is replaced by the DIR solution.

[M] **wind_speed** [011012] for the selected index is replaced by the DIR solution.

There are no record elements added for the SWS_Met MGDR. There are several header elements added, but only one affects the SWS_Met BUFR:

[D] **geophysical_model_function** [021119] is the name of the model function used in the wind retrieval. The valid values include `NSCAT-2`.

3.2 Creation of SWS_Met BUFR Data Elements

Most SWS_Met BUFR data elements are direct copies of SWS_Met MGDR data elements. The rest are either translated SWS_Met MGDR data elements, determined from SWS_Met MGDR data elements, assigned constants, or not currently used. Note that **sigma0** [021105] and related fields are reordered by beam i.e. flavor.

Some of the SWS_Met MGDR data elements are translated to agree with BUFR conventions or limitations.

[T] **PlatformLongName** [01007] is translated from a character string a to numeric value.

[T] **InstrumentShortName** [02048] is translated from a character string a to numeric value.

[T] **wvc_row_time** [004001/6] is converted from a character string to numeric values for year, month, day, hour, minute, and second. Seconds are truncated to whole seconds.

[T] **wvc_longitude** [006002] is converted to the range (-180,180).

[T] **build_id** [025060] is translated from a character string a to numeric value.

[T] **model_dir** [011081] is converted to the standard meteorological convention.

[T] **wind_dir** [011011] is converted to the standard meteorological convention.

[T] **cell_longitude** [006002] is converted to the range (-180,180).

[T] **kp_gamma** [021114] is converted to dB.

[T] **geophysical_model_function** [021119] is translated from a character string a to numeric value.

[T] **surface_flag** [008018], **wvc_quality_flag** [021109], **sigma0_quality_flag** [021115] and **sigma0_mode_flag** [021116] are translated to the BUFR bit convention. See more about BUFR bit flags in Section 3.

Some SWS_Met BUFR data elements have similar elements defined in the SIS, but are not present in the SWS_Met MGDR. Here we modify the definitions of these elements if necessary, and describe how the values for these elements are determined.

[C] **cell_index** [006034] is determined by position within the SWS_Met MGDR arrays.

[MC] **num_in_for** [021110] is set to one if σ^0 data is present for the inner-beam, forward flavor, and set to zero otherwise. (Unlike the SIS definition, if set to one this does not imply that the data was used for wind retrieval.)

The same approach is taken for **num_out_for** [021111], **num_in_aft** [021112], and **num_out_aft** [021113].

There are several fields in the SWS_Met BUFR which are created from the SWS_Met MGDR which have no corresponding SIS definitions. Here we give them SIS-like names, define them briefly, and describe how they are determined from the SWS_Met MGDR data elements, or otherwise assigned values.

[DC] **flight_angle** [001012] is the direction of motion measured clockwise from north.

The **flight_angle** [001012], denoted η is approximated as

$$\eta \approx \tan^{-1}(1/(\tan(\varphi)\cos(\phi))) + 2\pi,$$

where ϕ is the latitude for ascending orbit segments and π minus latitude for descending orbit segments, and φ is the orbit inclination angle. Latitude itself is approximated from **wvc_row** [005034], denoted N here, so that:

$$\phi \approx 2\pi(N - 0.5)/1624 - \pi/2.$$

Here we assume 25 km resolution (or 1624 rows for one full rev).

[DC] polarization [002104] is 0 for horizontal polarization, 1 for vertical polarization, and is inferred from bit 3 **sigma0_mode_flag** [021116]. (See Section 5.6.)

[DC] time_to_edge [004042] is the time difference from edge of processing segment.

Due to edge effects, data close to the edge may be incomplete or of poorer quality. (See Section 5.2.)

In addition SWS_Met BUFR includes

[DA] cross_track_resolution [002026], a constant 25 km;

[DA] along_track_resolution [002027], a constant 25 km; and

[DC] sigma0_variance_QC [021117], currently a place holder.

3.3 SWS_Met BUFR Record Structure

Each SWS_Met BUFR record is an independent package of data. Each record contains all observed data for an entire WVC row, which was available at the time of processing. If a given WVC contains no σ^0 measurements (and therefore no wind measurements), the WVC is not encoded in BUFR. A BUFR record may contain data from 1-76 WVCs depending on the number of observations present.

Storage is allowed in the data record for each of the four flavors of σ^0, in the order—inner-foreward, outer-foreward, inner-aft, outer-aft. For ocean cells containing sufficient σ^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** [021102]. The technique used to perform the ambiguity removal is implied by **build_id** [025060]. 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.

For each WVC, the data is organized as follows:

Descriptors 1–25: general WVC information.

Descriptors 26–29: WVC rain information.

Descriptors 30–49: ambiguous winds data. Space is allocated for four ambiguities.

Descriptors 50–57: Brightness temperature information. Space is allocated for horizontally and vertically polarized data.

Descriptors 58–117: σ^0 data. Space is allocated for one WVC composite per flavor.

An example WVC is listed here by a BUFR tool created at the European Centre for Medium-Range Weather Prediction (ECMWF). Note that in the listing ˜˜˜ indicates missing data.

```
BUFR DATA
  1.     281 Satellite Identifier [CODE TABLE   1007] (01007)
  2.     351 Direction Of Motion Of Moving Observing Platform [DEGREE TRUE] (01012)
  3.       8 Satellite Sensor Indicator [CODE TABLE   2048] (02048)
  4.       5 Wind Scatterometer Geophysical Model Function [CODE TABLE  21119] (21119)
  5.     231 Software Indentification [NUMERIC] (25060)
  6.   25000 Cross Track Resolution [M] (02026)
  7.   25000 Along Track Resolution [M] (02027)
  8.    3167 Orbit Number [NUMERIC] (05040)
  9.    1138 Time Difference From Edge Of Processing Segment [SECOND] (04042)
 10.    2000 Year [YEAR] (04001)
 11.       1 Month [MONTH] (04002)
 12.      27 Day [DAY] (04003)
 13.      20 Hour [HOUR] (04004)
 14.      45 Minute [MINUTE] (04005)
 15.       1 Second [SECOND] (04006)
 16.    5.03 Latitude (Coarse Accuracy) [DEGREE] (05002)
 17.   143.3 Longitude (Coarse Accuracy) [DEGREE] (06002)
 18.     425 Along Track Row Number [NUMERIC] (05034)
 19.      67 Cross Track Cell Number [NUMERIC] (06034)
 20.       0 Seawinds Wind Vector Cell Quality Flag [FLAG TABLE  21109] (21109)
 21.   40.09 Model Wind Direction At 10 M [DEGREE TRUE] (11081)
 22.    4.04 Model Wind Speed At 10 M [M/S] (11082)
 23.       3 Number Of Vector Ambiguities [NUMERIC] (21101)
 24.       2 Index Of Selected Wind Vector [NUMERIC] (21102)
 25.       4 Total Number Of Sigma-0 Measurements [NUMERIC] (21103)
 26.   0.013 Seawinds Probability Of Rain [NUMERIC] (21120)
 27.      47 Seawinds Nof Rain Index [NUMERIC] (21121)
 28.     ~~~ Rain Rate [KG/M**2HOUR] (13195)
 29.     ~~~ Attenuation Correction On Sigma-0 (From Tb) [dB] (21122)
 30.    4.69 Wind Speed At 10 M [M/S] (11012)
 31.    0.71 Formal Uncertainty In Wind Speed [M/S] (11052)
 32.   50.82 Wind Direction At 10 M [DEGREE TRUE] (11011)
 33.    1.32 Formal Uncertainty In Wind Direction [DEGREE TRUE] (11053)
 34.  -0.219 Likelihood Computed For Wind Solution [NUMERIC] (21104)
 35.    5.48 Wind Speed At 10 M [M/S] (11012)
 36.    0.48 Formal Uncertainty In Wind Speed [M/S] (11052)
 37.    9.41 Wind Direction At 10 M [DEGREE TRUE] (11011)
 38.    1.34 Formal Uncertainty In Wind Direction [DEGREE TRUE] (11053)
 39.  -0.529 Likelihood Computed For Wind Solution [NUMERIC] (21104)
 40.    5.55 Wind Speed At 10 M [M/S] (11012)
 41.    0.67 Formal Uncertainty In Wind Speed [M/S] (11052)
 42.  229.11 Wind Direction At 10 M [DEGREE TRUE] (11011)
 43.     1.4 Formal Uncertainty In Wind Direction [DEGREE TRUE] (11053)
 44.  -0.726 Likelihood Computed For Wind Solution [NUMERIC] (21104)
 45.     ~~~ Wind Speed At 10 M [M/S] (11012)
 46.     ~~~ Formal Uncertainty In Wind Speed [M/S] (11052)
```

```
47.      ~~~ Wind Direction At 10 M [DEGREE TRUE] (11011)
48.      ~~~ Formal Uncertainty In Wind Direction [DEGREE TRUE] (11053)
49.      ~~~ Likelihood Computed For Wind Solution [NUMERIC] (21104)
50.      ~~~ Antenna Polarisation [CODE TABLE   2104] (02104)
51.      ~~~ Total Number(With Respect To Accumulation Or Average) [NUMERIC] (08022)
52.      ~~~ Brightness Temperature [K] (12063)
53.      ~~~ Standard Deviation Brightness Temperature [K] (12065)
54.      ~~~ Antenna Polarisation [CODE TABLE   2104] (02104)
55.      ~~~ Total Number(With Respect To Accumulation Or Average) [NUMERIC] (08022)
56.      ~~~ Brightness Temperature [K] (12063)
57.      ~~~ Standard Deviation Brightness Temperature [K] (12065)
58.        1 Number Of Inner-Beam Sigma-0 (Forward Of Satellite) [NUMERIC] (21110)
59.     5.02 Latitude (Coarse Accuracy) [DEGREE] (05002)
60.    143.3 Longitude (Coarse Accuracy) [DEGREE] (06002)
61.      0.3 Attenuation Correction On Sigma-0 [dB] (21118)
62.    74.34 Radar Look Angle [DEGREE] (02112)
63.    46.38 Radar Incidence Angle [DEGREE] (02111)
64.        0 Antenna Polarisation [CODE TABLE   2104] (02104)
65.   -26.65 Seawinds Normalized Radar Cross Section [dB] (21123)
66.    1.004 Kp Variance Coefficient (Alpha) [NUMERIC] (21106)
67. 2.42e-06 Kp Variance Coefficient (Beta) [NUMERIC] (21107)
68.   -88.34 Kp Variance Coefficient (Gamma) [dB] (21114)
69.        0 Seawinds Sigma-0 Quality Flag [FLAG TABLE  21115] (21115)
70.      768 Seawinds Sigma-0 Mode Flag [FLAG TABLE  21116] (21116)
71.        0 Seawinds Land/Ice Surface Flag [FLAG TABLE   8018] (08018)
72.      ~~~ Sigma-0 Variance Quality Control [NUMERIC] (21117)
73.        1 Number Of Outer-Beam Sigma-0 (Forward Of Satellite) [NUMERIC] (21111)
74.     5.04 Latitude (Coarse Accuracy) [DEGREE] (05002)
75.    143.3 Longitude (Coarse Accuracy) [DEGREE] (06002)
76.      0.3 Attenuation Correction On Sigma-0 [dB] (21118)
77.    39.68 Radar Look Angle [DEGREE] (02112)
78.    53.98 Radar Incidence Angle [DEGREE] (02111)
79.        1 Antenna Polarisation [CODE TABLE   2104] (02104)
80.   -24.17 Seawinds Normalized Radar Cross Section [dB] (21123)
81.    1.008 Kp Variance Coefficient (Alpha) [NUMERIC] (21106)
82. 8.53e-06 Kp Variance Coefficient (Beta) [NUMERIC] (21107)
83.   -83.41 Kp Variance Coefficient (Gamma) [dB] (21114)
84.        0 Seawinds Sigma-0 Quality Flag [FLAG TABLE  21115] (21115)
85.     8960 Seawinds Sigma-0 Mode Flag [FLAG TABLE  21116] (21116)
86.        0 Seawinds Land/Ice Surface Flag [FLAG TABLE   8018] (08018)
87.      ~~~ Sigma-0 Variance Quality Control [NUMERIC] (21117)
88.        1 Number Of Inner-Beam Sigma-0 (Aft Of Satellite) [NUMERIC] (21112)
89.     5.01 Latitude (Coarse Accuracy) [DEGREE] (05002)
90.   143.29 Longitude (Coarse Accuracy) [DEGREE] (06002)
91.      0.3 Attenuation Correction On Sigma-0 [dB] (21118)
92.    87.28 Radar Look Angle [DEGREE] (02112)
93.    46.58 Radar Incidence Angle [DEGREE] (02111)
94.        0 Antenna Polarisation [CODE TABLE   2104] (02104)
95.   -27.39 Seawinds Normalized Radar Cross Section [dB] (21123)
96.    1.006 Kp Variance Coefficient (Alpha) [NUMERIC] (21106)
97. 5.91e-06 Kp Variance Coefficient (Beta) [NUMERIC] (21107)
```

```
 98.  -84.051 Kp Variance Coefficient (Gamma) [dB] (21114)
 99.       0 Seawinds Sigma-0 Quality Flag [FLAG TABLE  21115] (21115)
100.    4864 Seawinds Sigma-0 Mode Flag [FLAG TABLE  21116] (21116)
101.       0 Seawinds Land/Ice Surface Flag [FLAG TABLE   8018] (08018)
102.     ~~~ Sigma-0 Variance Quality Control [NUMERIC] (21117)
103.       1 Number Of Outer-Beam Sigma-0 (Aft Of Satellite) [NUMERIC] (21113)
104.    5.04 Latitude (Coarse Accuracy) [DEGREE] (05002)
105.  143.33 Longitude (Coarse Accuracy) [DEGREE] (06002)
106.     0.3 Attenuation Correction On Sigma-0 [dB] (21118)
107.  116.15 Radar Look Angle [DEGREE] (02112)
108.   53.99 Radar Incidence Angle [DEGREE] (02111)
109.       1 Antenna Polarisation [CODE TABLE   2104] (02104)
110.  -26.64 Seawinds Normalized Radar Cross Section [dB] (21123)
111.   1.008 Kp Variance Coefficient (Alpha) [NUMERIC] (21106)
112.  7.24e-06 Kp Variance Coefficient (Beta) [NUMERIC] (21107)
113.  -84.847 Kp Variance Coefficient (Gamma) [dB] (21114)
114.       0 Seawinds Sigma-0 Quality Flag [FLAG TABLE  21115] (21115)
115.   13056 Seawinds Sigma-0 Mode Flag [FLAG TABLE  21116] (21116)
116.       0 Seawinds Land/Ice Surface Flag [FLAG TABLE   8018] (08018)
117.     ~~~ Sigma-0 Variance Quality Control [NUMERIC] (21117)
```

3.4 SWS_Met BUFR Table B Descriptors

The previously defined Table B descriptors required are listed in Table 2. Some SWS_Met MGDR elements have greater or lesser precision than is allowed for by the BUFR tables. To accomodate these data, we use BUFR operator descriptors (of the form 2nnnnn) to temporarily change the scale and data width of certain elements. The scale and data widths after this modification are listed in Table 2 and are marked by a asterisk (*).

The new Table B descriptors required are listed in Tables 3 and 4. In all three tables, the last column, labeled "Source" indicates the corresponding SIS data element. The SIS data element name may be followed by square brackets containing one or more letter codes. These letter codes are defined at the start of Section 3 and indicate changes relative to the SIS. By implication if no code is noted than the SIS definitions apply directly.

Three previously existing code tables are referenced. New codes have been added to two.

- Code Table 001007, indicating the **PlatformLongName** [001007] or "SATELLITE IDENTIFIER" is given by Table 5. New codes are 280=ADEOS–1, 281=QuikSCAT, and 282=ADEOS–2.

- Code Table 002048, indicating the **InstrumentShortName** [002048] or "SATELLITE SENSOR INDICATOR" is defined by Table 6. New codes are 7=NSCAT and 8=SeaWinds.

- Code Table 002104, indicating the **polarization** [002104] or "ANTENNA POLARISATION" is defined by Table 7.

Four new flag tables and one new code table have been defined.

- Flag Table 008018, defining the bits in **surface_flag** [`008018`], is defined by Table 8.
- Flag Table 021109, defining the bits in **wvc_quality_flag** [`021109`], is defined by Table 9.
- Flag Table 021115, defining the bits in **sigma0_quality_flag** [`021115`], is defined by Table 10.
- Flag Table 021116, defining the bits in **sigma0_mode_flag** [`021116`], is defined by Table 11.
- Code Table 021119, indicating the **geophysical_model_function** [`021119`] is defined by Table 12.

Note that the SIS numbers bits starting with 0 for the least significant, but the BUFR convention starts with 1 for the most significant. However, bit order is reversed for these elements during translation. See Section 5.1 for more about BUFR bit flags.

Table 2: Previously existing Table B descriptors.

Desc.	Text description	Units	Scale	Offset	Bits	Source
001007	SATELLITE IDENTIFIER	CODE TABLE	0	0	10	**PlatformLongName [T]**
001012	DIRECTION OF MOTION OF MOVING OBSERVING PLATFORM	DEGREE TRUE	0	0	9	**flight_angle [DC]**
002104	ANTENNA POLARISATION	CODE TABLE	0	0	4	**polarization [DC]**
002111	RADAR INCIDENCE ANGLE	DEGREE	2*	0	13*	**cell_incidence [M]**
002112	RADAR LOOK ANGLE	DEGREE	2*	0	16*	**cell_azimuth [M]**
002026	CROSS TRACK RESOLUTION	M	-2*	0	12	25000 **[DA]**
002027	ALONG TRACK RESOLUTION	M	-2*	0	12	25000 **[DA]**
002048	SATELLITE SENSOR INDICATOR	CODE TABLE	0	0	4	**InstrumentShortName [T]**
004001	YEAR	NUMERIC	0	0	12	**wvc_row_time [T]**
004002	MONTH	NUMERIC	0	0	4	
004003	DAY	NUMERIC	0	0	6	
004004	HOUR	NUMERIC	0	0	5	
004005	MINUTE	NUMERIC	0	0	6	
004006	SECOND	NUMERIC	0	0	6	
005002	LATITUDE (COARSE ACCURACY)	DEGREE	2	-9000	15	**wvc_latitude** **cell_latitude**
005040	ORBIT NUMBER	NUMERIC	0	0	24	**rev_number [M]**
006002	LONGITUDE (COARSE ACCURACY)	DEGREE	2	-18000	16	**wvc_longitude [T]** **cell_longitude [T]**
008022	TOTAL NUMBER(WITH RESPECT TO ACCUMULATION OR AVERAGE)	NUMERIC	0	0	16	**num_tb_h** **num_tb_v**
011011	WIND DIRECTION AT 10 M	DEGREE TRUE	2*	0	16*	**wind_dir [MT]**
011012	WIND SPEED AT 10 M	M/S	2*	0	14*	**wind_speed [M]**
012063	BRIGHTNESS TEMPERATURE	K	1	0	12	**tb_mean_h** **tb_mean_v**
013195	RAIN RATE	KG/M**2HOUR	2*	0	13*	**tb_rain_rate**
025060	SOFTWARE IDENTIFICATION	NUMERIC	0	0	14	**build_id [MT]**

Table 3: New Table B descriptors.

Desc.	Text description	Units	Scale	Offset	Bits	Source
004042	TIME DIFFERENCE FROM EDGE OF PROCESSING SEGMENT	SECOND	0	0	14	**time_to_edge [DC]**
005034	ALONG TRACK ROW NUMBER	NUMERIC	0	0	11	**wvc_row**
006034	CROSS TRACK CELL NUMBER	NUMERIC	0	0	7	**cell_index [C]**
008018	SEAWINDS LAND/ICE SURFACE TYPE	FLAG TABLE	0	0	17	**surface_flag [T]**
011052	FORMAL UNCERTAINTY IN WIND SPEED	M/S	2	0	13	**wind_speed_err**
011053	FORMAL UNCERTAINTY IN WIND DIRECTION	DEGREE TRUE	2	0	15	**wind_dir_err**
011081	MODEL WIND DIRECTION AT 10 M	DEGREE TRUE	2	0	16	**model_dir [T]**
011082	MODEL WIND SPEED AT 10 M	M/S	2	0	14	**model_speed**
012065	STANDARD DEVIATION BRIGHTNESS TEMPERATURE	K	1	0	12	**tb_stddev_h** **tb_stddev_v**
021101	NUMBER OF VECTOR AMBIGUITIES	NUMERIC	0	0	3	**num_ambigs**
021102	INDEX OF SELECTED WIND VECTOR	NUMERIC	0	0	3	**wvc_selection**
021103	TOTAL NUMBER OF SIGMA-0 MEASUREMENTS	NUMERIC	0	0	5	**num_sigma0_per_cell**
021104	LIKELIHOOD COMPUTED FOR WIND SOLUTION	NUMERIC	3	-30000	15	**max_likelihood_est**
021106	Kp VARIANCE COEFFICIENT (ALPHA)	NUMERIC	3	0	14	**kp_alpha**
021107	Kp VARIANCE COEFFICIENT (BETA)	NUMERIC	8	0	16	**kp_beta**

Table 4: New Table B descriptors continued.

Desc.	Text description	Units	Scale	Offset	Bits	Source
021109	SEAWINDS WIND VECTOR CELL QUALITY	FLAG TABLE	0	0	17	**wvc_quality_flag [T]**
021110	NUMBER OF INNER-BEAM SIGMA-0 (FORWARD OF SATELLITE)	NUMERIC	0	0	6	**num_in_for [MC]**
021111	NUMBER OF OUTER-BEAM SIGMA-0 (FORWARD OF SATELLITE)	NUMERIC	0	0	6	**num_out_for [MC]**
021112	NUMBER OF INNER-BEAM SIGMA-0 (AFT OF SATELLITE)	NUMERIC	0	0	6	**num_in_aft [MC]**
021113	NUMBER OF OUTER-BEAM SIGMA-0 (AFT OF SATELLITE)	NUMERIC	0	0	6	**num_out_aft [MC]**
021114	Kp VARIANCE COEFFICIENT (GAMMA)	dB	3	-140000	18	**kp_gamma [T]**
021115	SEAWINDS SIGMA-0 QUALITY	FLAG TABLE	0	0	17	**sigma0_quality_flag [T]**
021116	SEAWINDS SIGMA-0 MODE	FLAG TABLE	0	0	17	**sigma0_mode_flag [T]**
021117	SIGMA-0 VARIANCE QUALITY CONTROL	NUMERIC	2	0	16	**sigma0_variance_QC [DC]**
021118	ATTENUATION CORRECTION ON SIGMA-0	dB	2	-10000	14	**sigma0_atten_map**
021119	WIND SCATTEROMETER GEOPHYSICAL MODEL FUNCTION	CODE TABLE	0	0	6	**geophysical_model_function [DT]**
021120	SEAWINDS PROBABILITY OF RAIN	NUMERIC	3	0	10	**mp_rain_probability**
021121	SEAWINDS NOF RAIN INDEX	NUMERIC	0	0	8	**nof_rain_index**
021122	ATTENUATION CORRECTION ON SIGMA-0 (FROM TB)	dB	2	-10000	14	**tb_attenuation**
021123	SEAWINDS NORMALIZED RADAR CROSS SECTION	dB	2	-30000	15	**sigma0**

Table 5: Code Table 001007: translated from **PlatformLongName** [001007].

Code figure	Meaning	Code figure	Meaning
1	ERS1	241	DMSP 8
2	ERS2	242	DMSP 9
20	SPOT1	243	DMSP 10
21	SPOT2	244	DMSP 11
50	METEOSAT	250	GOES 6
51	METEOSAT 4	251	GOES 7
150	GMS 3	252	GOES 8
151	GMS 4	253	GOES 9
200	NOAA 8	254	GOES 10
201	NOAA 9	255	GOES 11
202	NOAA 10	256	GOES 12
203	NOAA 11	280	ADEOS1
220	LANDSAT 5	281	QUIKSCAT
221	LANDSAT 6	282	ADEOS2
240	DMSP 7	1023	MISSING VALUE

Table 6: Code Table 002048: translated from **InstrumentShortName** [002048].

Code figure	Meaning	Code figure	Meaning
0	HIRS	6	SSMI
1	MSU	7	NSCAT
2	SSU	8	SEAWINDS
3	AMSU-A	9-14	RESERVED
4	AMSU-B	15	MISSING VALUE
5	AVHRR		

Table 7: Code Table 002104: Polarization (translated from **sigma0_mode_flag** [002104]).

Code figure	Meaning
0	HORIZONTAL POLARISATION
1	VERTICAL POLARISATION
2	RIGHT CIRCULAR POLARISATION
3	LEFT CIRCULAR POLARISATION
4	HORIZONTAL AND VERTICAL POLARISATION
5	RIGHT AND LEFT CIRCULAR POLARISATION
15	MISSING VALUE

Table 8: Flag Table 008018: **surface_flag** [008018].

Bit number	Meaning
1	LAND IS PRESENT
2	SURFACE ICE MAP INDICATES ICE IS PRESENT
3-10	RESERVED
11	ICE MAP DATA NOT AVAILABLE
12	ATTENUATION MAP DATA NOT AVAILABLE
13-16	RESERVED
All 17	MISSING VALUE

Table 9: Flag Table 021109: **wvc_quality_flag** [021109].

Bit number	Meaning
1	NOT ENOUGH GOOD SIGMA-0 AVAILABLE FOR WIND RETRIEVAL
2	POOR AZIMUTH DIVERSITY AMONG SIGMA-0 FOR WIND RETRIEVAL
3-7	RESERVED
8	SOME PORTION OF WIND VECTOR CELL IS OVER LAND
9	SOME PORTION OF WIND VECTOR CELL IS OVER ICE
10	WIND RETRIEVAL NOT PERFORMED FOR WIND VECTOR CELL
11	REPORTED WIND SPEED IS GREATER THAN 30 M/S
12	REPORTED WIND SPEED IS LESS THAN 3 M/S
13	MULTI-PARAMETER RAIN PROBABILITY RAIN FLAG IS NOT USABLE
14	MULTI-PARAMETER RAIN PROBABILITY DETECTS RAIN
15	NORMALIZED OBJECTIVE FUNCTION RAIN FLAG IS NOT USABLE
16	NORMALIZED OBJECTIVE FUNCTION DETECTS RAIN
All 17	MISSING VALUE

Table 10: Flag Table 021115: **sigma0_quality_flag** [021115].

Bit number	**Meaning**
1	SIGMA-0 MEASUREMENT IS NOT USABLE
2	SIGNAL TO NOISE RATIO IS LOW
3	SIGMA-0 IS NEGATIVE
4	SIGMA-0 IS OUTSIDE OF ACCEPTABLE RANGE
5	SCATTEROMETER PULSE QUALITY IS NOT ACCEPTABLE
6	SIGMA-0 CELL LOCATION ALGORITHM DOES NOT CONVERGE
7	FREQUENCY SHIFT LIES BEYOND THE RANGE OF THE X FACTOR TABLE
8	SPACECRAFT TEMPERATURE IS BEYOND CALIBRATION COEFFICIENT RANGE
9	NO APPLICABLE ATTITUDE RECORDS WERE FOUND FOR THIS SIGMA-0
10	INTERPOLATED EPHEMERIS DATA ARE NOT ACCEPTABLE FOR THIS SIGMA-0
11-16	RESERVED
All 17	MISSING VALUE

Table 11: Flag Table 021116: **sigma0_mode_flag** [021116]. Refer to the Level 2A SIS [16] for definitions of multi-bit fields.

Bit number	Meaning
1	CALIBRATION/MEASUREMENT PULSE FLAG (1)
2	CALIBRATION/MEASUREMENT PULSE FLAG (2)
3	OUTER ANTENNA BEAM
4	SIGMA-0 CELL IS AFT OF SPACECRAFT
5	CURRENT MODE (1)
6	CURRENT MODE (2)
7	EFFECTIVE GATE WIDTH - SLICE RESOLUTION (1)
8	EFFECTIVE GATE WIDTH - SLICE RESOLUTION (2)
9	EFFECTIVE GATE WIDTH - SLICE RESOLUTION (3)
10	LOW RESOLUTION MODE - WHOLE PULSE DATA
11	SCATTEROMETER ELECTRONIC SUBSYSTEM B
12	ALTERNATE SPIN RATE - 19.8 RPM
13	RECEIVER PROTECTION ON
14	SLICES PER COMPOSITE FLAG (1)
15	SLICES PER COMPOSITE FLAG (2)
16	SLICES PER COMPOSITE FLAG (3)
All 17	MISSING VALUE

Table 12: Code Table 021119: **geophysical_model_function** [021119].

Code figure	Meaning	Code figure	Meaning
0	RESERVED	8-30	RESERVED
1	SASS	31	CMOD1
2	SASS2	32	CMOD2
3	NSCAT0	33	CMOD3
4	NSCAT1	34	CMOD4
5	NSCAT2	35	CMOD5
6	QSCAT0	36-63	RESERVED
7	QSCAT1	64	MISSING VALUE

3.5 SWS_Met BUFR Table D Descriptors

New Table D descriptors (common sequences) for ambiguous wind data, σ^0 data and the entire subset have been defined. As a result, a WVC is represented by one Table D descriptor: 312028. This one descriptor expands as follows:

```
312028 23                    SeaWinds 25km data with rain flags
           301046 10         SeaWinds header information
                    001007   SATELLITE IDENTIFIER
                    001012   DIRECTION OF MOTION OF MOVING OBSERVING PLATFORM
                    002048   SATELLITE SENSOR INDICATOR
                    021119   WIND SCATTEROMETER GEOPHYSICAL MODEL FUNCTION
                    025060   SOFTWARE INDENTIFICATION
                    202124   *** decrease scaling by 10^4
                    002026   ALONG TRACK RESOLUTION
                    002027   CROSS TRACK RESOLUTION
                    202000   *** cancel change scaling
                    005040   ORBIT NUMBER
           004042            TIME DIFFERENCE FROM EDGE OF PROCESSING SEGMENT
           301011  3         Date information
                    004001   YEAR
                    004002   MONTH
                    004003   DAY
           301013  3         Time information
                    004004   HOUR
                    004005   MINUTE
                    004006   SECOND
           301023  2         Position information
                    005002   LATITUDE (COARSE ACCURACY)
                    006002   LONGITUDE (COARSE ACCURACY)
           312031  8         Seawinds WVC information
                    005034   ALONG TRACK ROW NUMBER
                    006034   CROSS TRACK CELL NUMBER
                    021109   QSCAT WIND VECTOR CELL QUALITY FLAG
                    011081   MODEL WIND DIRECTION AT 10 M
                    011082   MODEL WIND SPEED AT 10 M
                    021101   NUMBER OF VECTOR AMBIGUITIES
                    021102   INDEX OF SELECTED WIND VECTOR
                    021103   TOTAL NUMBER OF SIGMA-0 MEASUREMENTS
           312032  8         Seawinds Rain Flagging Information
                    021120   SEAWINDS PROBABILITY OF RAIN
                    021121   SEAWINDS NOF RAIN INDEX
                    201136   *** increase data width by 8 bits
                    202130   *** increase scaling by 10^2
                    013195   RAIN RATE
                    202000   *** cancel change scaling
                    201000   *** cancel change data width
                    021122   ATTENUATION CORRECTION ON SIGMA-0 (FROM Tb)
           101004            *** replicate 1 descriptor 4 times
           312030 13         Seawinds ambiguous wind data
                    201130   *** increase data width by 2 bits
```

```
          202129   *** increase scaling by 10^1
          011012   WIND SPEED AT 10 M
          202000   *** cancel change scaling
          201000   *** cancel change data width
          011052   FORMAL UNCERTAINTY IN WIND SPEED
          201135   *** increase data width by 7 bits
          202130   *** increase scaling by 10^2
          011011   WIND DIRECTION AT 10 M
          202000   *** cancel change scaling
          201000   *** cancel change data width
          011053   FORMAL UNCERTAINTY IN WIND DIRECTION
          021104   LIKELIHOOD COMPUTED FOR SOLUTION
101002             *** replicate 1 descriptor 2 times
312033  4          Seawinds Brightness Temp. Information
          002104   ANTENNA POLARISATION
          008022   TOTAL NUMBER(WITH RESPECT TO ACCUMULATION OR AVERAGE)
          012063   BRIGHTNESS TEMPERATURE
          012065   STANDARD DEVIATION BRIGHTNESS TEMPERATURE
021110             NUMBER OF INNER-BEAM SIGMA-0 (FORWARD OF SATELLITE)
301023    (above)  Position information
321027 18          SeaWinds Sigma-0 data
          021118   ATTENUATION CORRECTION ON SIGMA-0
          202129   *** increase scaling by 10^1
          201132   *** increase data width by 4 bits
          002112   RADAR LOOK ANGLE
          201000   *** cancel change data width
          201131   *** increase data width by 3 bits
          002111   RADAR INCIDENCE ANGLE
          201000   *** cancel change data width
          202000   *** cancel change scaling
          002104   ANTENNA POLARISATION
          021123   SEAWINDS NORMALIZED RADAR CROSS SECTION
          021106   Kp VARIANCE COEFFICIENT (ALPHA)
          021107   Kp VARIANCE COEFFICIENT (BETA)
          021114   Kp VARIANCE COEFFICIENT (GAMMA)
          021115   SEAWINDS SIGMA-0 QUALITY FLAG
          021116   SEAWINDS SIGMA-0 MODE FLAG
          008018   SEAWINDS LAND/ICE SURFACE FLAG
          021117   SIGMA-0 VARIANCE QUALITY CONTROL
021111             NUMBER OF OUTER-BEAM SIGMA-0 (FORWARD OF SATELLITE)
301023    (above)  Position information
321027    (above)  SeaWinds Sigma-0 data
021112             NUMBER OF INNER-BEAM SIGMA-0 (AFT OF SATELLITE)
301023    (above)  Position informationlat/lon
321027    (above)  SeaWinds Sigma-0 data
021113             NUMBER OF OUTER-BEAM SIGMA-0 (AFT OF SATELLITE)
301023    (above)  Position information
321027    (above)  SeaWinds Sigma-0 data
```

4 Reading SWS_Met BUFR Data Files

4.1 Reading SWS_Met BUFR Records

The World Meteorological Organization (WMO) sets the standards for BUFR data, and therefore, BUFR data may be read and decoded in any way that conforms to the WMO standard. The ECMWF BUFR software suite is used here to illustrate reading and decoding BUFR records.

BUFR records are conveniently read by C routines since the data are bit-oriented, not FORTRAN word or record-oriented. After opening the file, these routines search for BUFR record delimiters ("BUFR" and "7777") in the input file stream and return one unexpanded record. An unexpanded record may be compressed and contains unscaled values.

The following are example calls to open a BUFR file and read one BUFR record.

```
CALL PBOPEN(IUNIT,INFILE,'R',IRET)
CALL PBBUFR(IUNIT,KBUFF,JBYTE,KBUFL,IRET)
```

where, for `PBOPEN`

- `IUNIT` - output - integer unit number for the file
- `INFILE` - input - character file name of input BUFR file with no trailing blanks
- `'R'` - input - character specifies "read only"
- `IRET` - output - integer 0 if a BUFR file has been successfully opened

and for `PBBUFR`,

- `IUNIT` - input - integer unit number for the file returned from `PBOPEN`
- `KBUFF` - output - integer FORTRAN array big enough to hold the BUFR product
- `JBYTE` - input - integer size in BYTES of the FORTRAN array
- `KBUFL` - output - integer size in BYTES of the BUFR product read
- `IRET` - output - integer 0 if a BUFR product has been successfully read

4.2 Decoding SWS_Met BUFR Records

Once a BUFR record has been read, it must be expanded from a bit stream to real values. An unexpanded BUFR product is decoded in two stages. First, sections 0-2 are decoded to determine the total length of the record and number of subsets. Next, this information and the unexpanded record are passed to `BUFREX` which decodes the entire BUFR record into fully expanded form; returning information relevant for all BUFR sections, expanded values, their names and units. `BUFREX` also uncompresses the record if the input record is compressed.

The following is an example of decoding one BUFR record in two stages.

```
      CALL BUS012(KBUFL,KBUFF,KSUP,KSEC0,KSEC1,KSEC2,KERR)
      CALL BUFREX(KBUFL,KBUFF,KSUP,KSEC0,KSEC1,KSEC2,
     1            KSEC3,KSEC4,KEL,CNAMES,CUNITS,KVALS,
     2            VALUES,CVALS,KERR)
```

where, for `BUS012`,

- `KBUFL` - input - integer length of BUFR record in words
- `KBUFF` - input - integer array containing BUFR record
- `KSUP` - output - integer array containing supplementary information
- `KSEC0, KSEC1, KSEC2` - output - integer array containing BUFR information from sections 0-2
- `KERR` - output - integer 0 if sections 0-2 were decoded successfully

and for `BUFREX`, similar definitions for the first six and last arguments as in `BUS012` with the addition of

- `KSEC3, KSEC4` - output - integer array containing BUFR information from sections 3, and 4
- `KEL` - input - integer expected number of expanded elements
- `CNAMES, CUNITS` - output - character arrays containing names and units of `KEL` elements
- `KVALS` - input - integer expected number of data values
- `VALUES` - output - real array of data values
- `CVALS` - output - character array containing full Table B entries

For more information on the BUFR standard, see WMO [19]. For more information on the ECMWF BUFR software suite, see Dragosavac [1].

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 σ^0 values are ordered by flavors—inner-foreward, outer-foreward, inner-aft, outer-aft.

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 [15, 16, 17]. 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).

All bit flags from the SWS_Met MGDR are reversed prior to coding into BUFR, and an additional bit is added if necessary to indicate missing data. To illustrate, consider an 8-bit SWS_Met MGDR flag:

	Most							Least	Significant Bit
MGDR bit	7	6	5	4	3	2	1	0	
bit value	0	0	0	0	0	1	0	1	

Now the same 8-bit flag as represented in BUFR:

	Most								Least	Significant Bit
BUFR bit	1	2	3	4	5	6	7	8	9	
bit value	1	0	1	0	0	0	0	0	0	

Given a BUFR bit number, n_B, the equivalent MGDR bit number, n_M is found simply by subtracting one,

$$n_M = n_B - 1.$$

Because of the bit reversal, if a BUFR flag is stored as an integer in a FORTRAN program, use `BTEST(I,NDW-NB-1)` to test bit `NB`, where `NDW` is the width in bits of the data element in BUFR.

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 10 of **wvc_quality_flag** [`021109`] is set), then high and low wind speed flag processing is bypassed, and bits 11 and 12 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 9 of **wvc_quality_flag** [`021109`] and bit 2 of **surface_flag** [`008018`]. [Note that the BUFR convention of numbering bits is used here.]

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 [15, 16, 17]. 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 σ^0 values, but σ^0 values are divided strictly by rev, and some WVC rows near the south pole will have σ^0 values in two files, with foreward flavored σ^0 one rev behind the aft flavored σ^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 σ^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 σ^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** [004001/6] will be close to identical. A better approach is to match **wvc_row** [005034] and **rev_number** [005040], 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** [005034] for a single rev.)

For a given WVC row that repeats, the data values may be identical or different, depending on whether additional σ^0 values are present in one of the WVC row records. In this case, we eliminate the record which has fewer σ^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. Therefore, we have added **time_to_edge** [004042], which indicates the time difference to the nearest edge of the data pass. Then, when repeating WVC rows are detected, keep the one with the largest value of **time_to_edge** [004042]. [***TBD: At some later time, for convenience, elements* rev_number *[*005040*], *wvc_row *[*005034*], and* time_to_edge *[*004042*] may be repeated in* `ksec2(1)` *so that sorting messages and choosing between repeating WVC rows may be accomplished without decoding the body of each message.***]

5.3 Ocean Wind Vector Data

The ocean wind vector data are contained in data elements

> **wind_speed** [011012];
> **wind_speed_err** [011052];
> **wind_dir** [011011];
> **wind_dir_err** [011053]; and
> **max_likelihood_est** [021104].

These are BUFR elements 30–49. Use **num_ambigs** [021101] to determine the number of non-missing wind ambiguities. If **num_ambigs** [021101] is n, then the first n locations for each wind data element will contain data. If the σ^0 data are not of sufficient quality or over land or ice, $n = 0$, all wind data elements, including **wvc_selection** [021102], will be missing, and bit 10 of **wvc_quality_flag** [021109] will be set.

Several other data quality indicators are also present in **wvc_quality_flag** [021109], including whether there are not enough good σ^0 values for wind retrieval (bit 1); whether there is not enough azimuthal diversity for wind retrieval (bit 2); whether some land is within the WVC (bit 8); whether some ice is within the WVC (bit 9); whether the retrieved wind speed is $> 30\ m/s$ (bit 11); and whether the retrieved wind speed is $< 3\ m/s$ (bit 12). Currently bit 13 through bit 16 are used to store experimental rain flags. See Table 9. For more details see the Level 2B SIS.

It is important to note that all wind directions in the SWS_Met BUFR are given in the "meteorological" convention, i.e. wind flowing toward the North is defined as 180 degrees, with positive angles increasing in the clockwise direction. That is, the direction is the direction from which the air flows. To convert from speed and direction denoted (U, ϕ) 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 [021120];
nof_rain_index [021121];
tb_rain_rate [013195]; and
tb_attenuation [021122].

These are BUFR elements 26–29.

The **mp_rain_probability** [021120] and **nof_rain_index** [021121] are described in the Level 2B SIS. Because these elements depend on the σ^0 values, separate tables and thresholds were developed for the WVC-composites.

Currently **tb_rain_rate** [013195] and **tb_attenuation** [021104] are placeholders.

5.5 Brightness temperature information

Experimental brightness temperature information is included in data elements

tb_mean_h [012063];
tb_mean_v [012063];
tb_stddev_h [012065];
tb_stddev_v [012065];
num_tb_h [008022]; and
num_tb_v [008022].

In SWS_Met BUFR these elements are identified as being either horizontally or vertically polarized by **polarization** [002104]. The brightness temperature information is held in BUFR elements 50–57.

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 σ^0 Data

The σ^0 data are contained in

cell_latitude [005002];
cell_longitude [006002];
sigma0_atten_map [021118];
cell_azimuth [002112];
cell_incidence [002111];
polarization [002104];
sigma0 [021105];
kp_alpha [021106];
kp_beta [021107];
kp_gamma [021114];
sigma0_variance_QC [021117];
sigma0_quality_flag [021115];
sigma0_mode_flag [021116]; and
surface_flag [008018].

These are within BUFR elements 58-117. The total number of WVC-composite σ^0 values in a WVC is given by **num_sigma0_per_cell** [021103]. To determine those σ^0 data elements which contain data, examine **num_in_fore** [021110], **num_out_fore** [021111], **num_in_aft** [021112], and **num_out_aft** [021113]. Each of these elements will have a value of zero or one if the WVC-composite corresponding to the associated "flavor" is missing or present, respectively. When a σ^0 value is missing, all associated variables are also missing.

There are three bit flag data elements relevant to the use of the σ^0 data. These are the **sigma0_mode_flag** [021116], **sigma0_quality_flag** [021115], and **surface_flag** [008018]. In general, all three should be examined when using σ^0 values.

The **sigma0_mode_flag** [021116] indicates the instrument mode and status associated with the σ^0 value. Bits 3 and 4 of **sigma0_mode_flag** [021116] may be used to verify the "flavor" of each value; in particular, bit 3 of **sigma0_mode_flag** [021116] may be used to determine which antenna beam corresponds to a particular σ^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** [002104]. In addition, for usable geophysical data, bits 1, 2, 5, and 6 must be zero.

If **sigma0_quality_flag** [021115] bit 1 is zero, then the associated individual σ^0 value is usable from the engineering point of view. If bit 1 is set to one, then bits 2 and 4–10 may be helpful in identifying the reason why the value is not considered usable. NOTE that if the σ^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 3 of the **sigma0_quality_flag** [021115], denoted s here, indicates whether the normal (ratio) space σ^0 is negative. Any use of the σ^0 values must take into account this bit flag. The σ^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 σ^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** [021105] values are the observed top of the atmosphere values. These values should be corrected for atmospheric effects. The **sigma0_atten_map** [021118] values are the rain-free two-way nadir attenuation corrections to be applied to the σ^0 data based on the monthly Wentz-SSM/I climatology. The value does not include the $\sec\theta$ correction, where θ 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 τ is the one-way transmittance, itself given by,

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

where α is the atmospheric opacity in the vertical, measured in *napers*. Converting to decibels and solving for σ^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** [021118] multiplied by $\sec\theta$ is added in dB space to the value of **sigma0** [021105]. Here

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

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

In the case of negative σ^0, $(s = 1)$, the atmospheric correction described in the previous paragraph does not apply. One could replace σ^0 by $|\sigma^0|$ everywhere in the above development and obtain the same answer for these cases as well. However, when σ^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 σ^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 σ^0 is corrected to a less negative σ^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 σ^0 data for all surface types. The surface type may be inferred from **surface_flag** [008018], bit 1 and bit 2. If bit 1 is set to one, then land is present; if bit 2 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 11 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 2 will be cleared to zero. Finally bit 12 of **surface_flag** [008018] should always be cleared to zero, indicating that an attenuation map was available.

5.7 K_p Modeling

The **max_likelihood_est** [021104] is the value of the objective function which is maximized, divided by the number of σ^0 WVC-composites used. The objective function is the negative of the sum of squared differences between observed and modeled σ^0 values, where each squared difference is normalized by its expected variance, ε^2.

Three coefficients, denoted here as α, β and γ, are used to calculate ε^2, according to

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

The values of α, β, and γ are stored in data elements **kp_alpha** [021106], **kp_beta** [021107], and **kp_gamma** [021107]. NOTE that the value of γ is converted to dB before it is stored in BUFR. To convert back to a ratio use

$$\gamma[\text{ratio}] = 10^{(\gamma[dB]/10)}.$$

Together the coefficients α, β and γ 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 σ^0 used here should be the modeled value. That is, during wind retrieval, it is the estimate of σ^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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- Corrections and updates to this User's Guide should be referred to:

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8 References

Many of the newer JPL reports, including the Software Interface Specifications [15, 16, 17], can be found at:

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

In addition [5, 6, 3] contain interesting background information.

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9 List of Acronyms

ADCS TBD

BUFR Binary Universal Form for the Representation of Meteorological Data

BYU Brigham Young University

C/A TBD

CSC Computer Sciences Corp.

dB Decibels

ECMWF European Centre for Medium-Range Weather Forecasts

ERS-1 European Remote-sensing Satellite 1

FFT fast Fourier transform

FORTRAN FORTRAN

GHz Gigahertz

GPS Global Positioning System

GSFC Goddard Space Flight Center

HDF Hierarchical Data Format

IRU TBD

JPL Jet Propulsion Laboratory

Kbps kilobits per second

Mbps megabits per second

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

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

SSM/I Special Sensor Microwave/Imager

SeaWinds SeaWinds

SWS_Met SWS Real-Time Data Product

SWS_Sci SWS Science Data Product

TBD to be determined

UTC Coordinated Universal Time

WMO World Meteorological Organization

WVC Wind Vector Cell