ERS PRODUCTS

WMO FM94 BUFR FORMAT

ER-IS-UKM-GS-0001
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ERS PRODUCTS
WMO FM94 BUFR FORMAT

Acronyms and Abbreviations

ASST	Averaged Sea Surface Temperature
ATSR	Along Track Scanning Radiometer
BUFR	Binary Universal Format for data Representation. A WMO approved encoding method otherwise known as Format Number 94 (FM94)
DEC *	Digital Equipment Corporation
DCL	Digital Command Language (VMS command line interpreter)
ECMWF	European Centre for Medium-Range Weather Forecasts
ERS	European Remote Sensing satellite
ESA	European Space Agency
FDP	Fast Delivery Product
GTS	Global Telecommunications System
ISS	Interface Sub-System. ESA facility for the distribution of ERS data
LBR	Low Bit Rate
MPH	Main Product Header
OpenVMS	Common operating system for DEC VAX and Alpha architectures
PCD	Product Confidence Data
RAL	Rutherton Appleton Laboratory
RMS	Record Management System. Part of VMS
SADIST	Synthesis of ATSR Data Into Sea-surface Temperatures. Processing software system for ATSR data (RAL). SADIST (V600) for ATSR on ERS-1 only, upgraded to SADIST-2 for ATSR-2 on ERS-2
SPH	Specific Product Header
SST	Sea Surface Temperature
VMS *	Virtual Memory System. DEC VAX operating system.
WMO	World Meteorological Organisation

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1. Introduction

1.1 Scope

This document defines all the products distributed by ESA/ESRIN for transmission over the World Meteorological Organisation (WMO) Global Telecommunication System (GTS). Products are defined in terms of their structure, content and format.

The products described are the WMO FM94 BUFR encoded versions of the following four Low Bit Rate (LBR) Fast Delivery Products (FDP):-

UAT - ATSR (ASST) data,
URA - Radar Altimeter data,
UWA - Wave Scatterometer data,
UWI - Wind Scatterometer data.

1.2 Document Overview

This document provides the definition and format of the WMO FM94 BUFR formatted versions of the ERS-1 and ERS-2 products listed in Section 1.1. This document should be used in conjunction with documents referenced as [A3] and [A4] in Section 1.3.

1.3 Applicable Documents

[A1]. ER-IS-MDA-GS-0210, Issue 1/0.	ESA/Earthnet. ERS-2 Kiruna Station Users Interface Specification, 5 April 1994.
[A2]. ER-TN-ESA-GS-0324, Issue 1.	UWA processing algorithm specification, Version 2, 7 November 1996
[A3]. ER-MA-UKM-GS-0001, Version 4.	ESA/ESRIN. FM94 BUFR Encoding software for ERS data, Software User Manual (Software Release V5.00).
[A4]. ER-MA-UKM-GS-0002, Version 4.	ESA/ESRIN. FM94 BUFR Decoding software for ERS data, Software User Manual. (Software Release V5.00)
[A5] P. Bailey.	SADIST-2 v100 Products. ER-TN-RAL-AT-2164, 6 September 1995

1.4 Referred Documentation

[R1]. ER-SD-UKM-GS-0001, Version 4.	ESA/ESRIN. FM94 BUFR Encoding software for ERS data, Detailed Design Document. (Software Release V5.00).
[R2]. ER-SD-UKM-GS-0002, Version 4.	ESA/ESRIN. FM94 BUFR Decoding software for ERS data, Detailed Design Document. (Software Release V5.00).
[R3]. WMO-306	WMO, Geneva. Manual on Codes, Vol.1.2, Part B, 1995 Edition with Supplement No.3, August 1998.

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2. Product Generation

2.1 Introduction

This section gives a description of all the products encoded at ESA/ESRIN into the World Meteorological Organisation (WMO) FM94 BUFR format for distribution over the WMO Global Telecommunication System (GTS). The products encoded for transmission over the WMO GTS are:

UAT - ATSR (ASST) data,
URA - Radar Altimeter data,
UWA - Wave Scatterometer data,
UWI - Wind Scatterometer data.

2.2 Product Generation

The products are generated in encoded form at ESA/ESRIN, Frascati, and then distributed to customers via the WMO GTS.

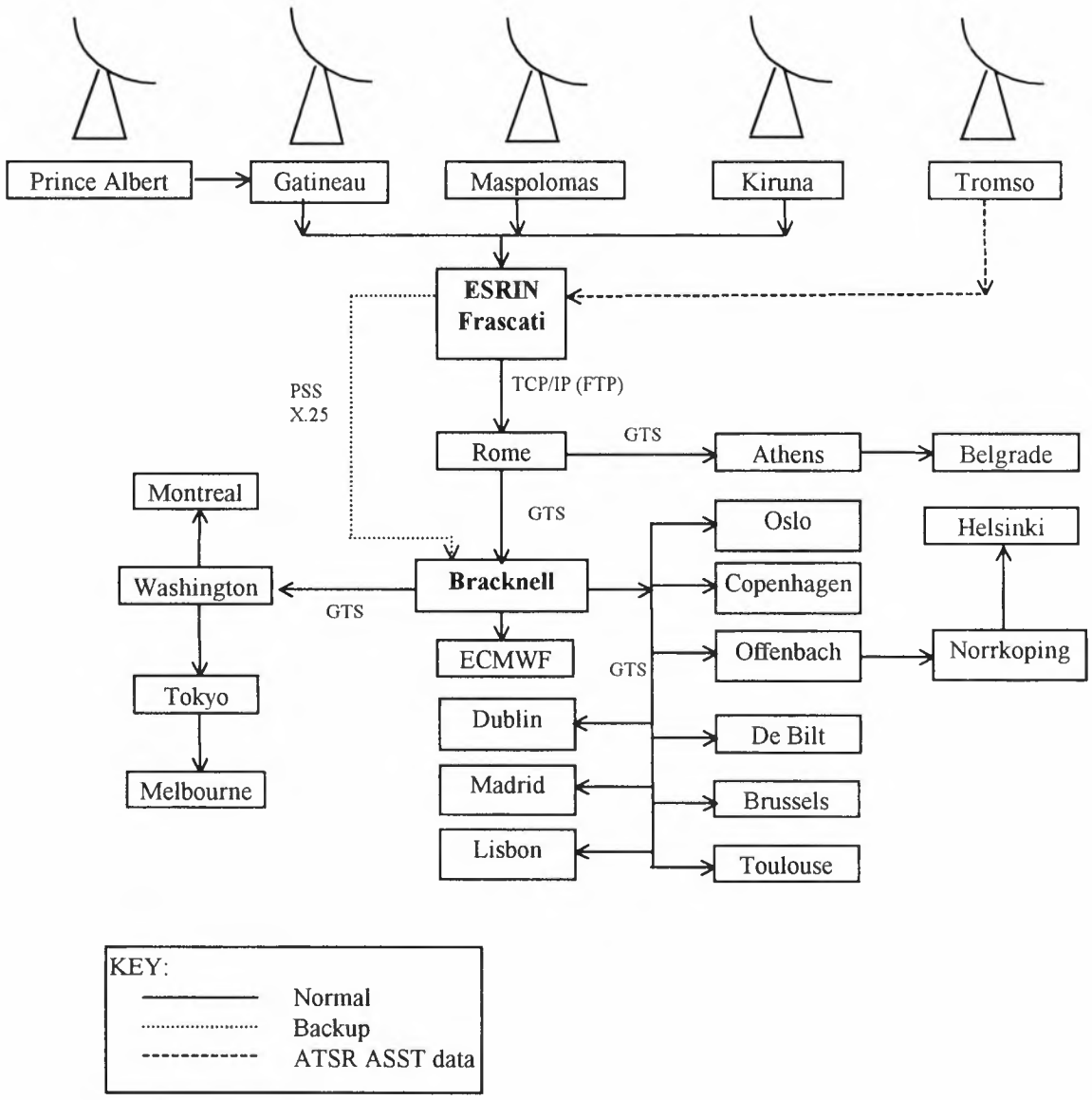
The encoded products are generated from the equivalent Low Bit Rate (LBR) Fast Delivery Products (FDP) received at Frascati from the various ground stations. Encoding and transmission of a product takes place in near real time.

Distribution is normally via a TCP/IP (FTP) telecommunications link to the Italian Meteorological Service in Rome where products are injected on to the GTS for routing to customers via existing GTS or GTS compatible links. A back-up link exists via the GTS node in Bracknell, UK. The distribution is summarised in Figure 2.1 and Table 2.1.

2.3 Applicability statement

The products described in this document are those generated by Version 5.xx of the software that encodes the ERS-1 and ERS-2 Low Bit Rate (LBR) Fast Delivery Products (FDP) into the World Meteorological Organisation (WMO) FM94 BUFR format for transmission over the WMO Global Telecommunications System (GTS).

Figure 2.1 – ERS Data Distribution



Schematic of ERS Fast Delivery Product distribution. National Meteorological Centres may also route to local users

Table 2.1: FDP Products and Areas of coverage required by customers

National Customer Centre	*Products and areas*				*Routing*	
	UWI	*UWA*	*URA*	*UAT*	*Via*	*Backup*
Athens	D	D	D		Rome	
Belgrade	A,D,E,H	-	-		Athens	
Bracknell	A-L	A-L	A-L	A-L	Rome	ESRIN
Brussels	?	?	?		Bracknell	Toulouse
Copenhagen	A,D	A,D	A,D		Bracknell	
De Bilt	A,D	A,D	A,D	A,D	Bracknell	
Dublin	A	-	A		Bracknell	
ECMWF	A-L	A-L	A-L		Bracknell	
Lisbon	A	A	A		Bracknell	Toulouse
Madrid	A,D,E	A,D,E	A,D,E		Bracknell	Toulouse
Melbourne	A-L	A-L	A-L		Tokyo	
Montreal	A-L	A-L	A-L		Washington	
Norrköping	A,D	A,D	A,D		Offenbach	Copenhagen
Offenbach	A-L	A-L	A-L		Bracknell	Toulouse
Oslo	A,D	A,D	A,D		Bracknell	
Rome (routing)	A-L	A-L	A-L		ESRIN	Bracknell
Rome (local use)	D	D	D			
Tokyo	A-L	A-L	A-L		Washington	
Toulouse	A-L	A-L	A-L	A-L	Bracknell	Rome?
Washington	A-L	A-L	A-L	A-L	Bracknell	

See Table 2.2 for definition of WMO area code letters.

Table 2.2: Area Codes

Code	*Latitude band*	*Longitude segment*
A	90°N - 30°N	0°W - 90°W
B	90°N - 30°N	90°W - 180°W
C	90°N - 30°N	180°E - 90°E
D	90°N - 30°N	90°E - 0°E
E	30°N - 30° S	0°W - 90°W
F	30°N - 30°S	90°W - 180°W
G	30°N - 30°S	180°E - 90 °E
H	30°N - 30°S	90°E - 0°E
I	30°S - 90°S	0°W - 90°W
J	30°S - 90°S	90°W - 180°W
K	30°S - 90°S	180°E - 90°E
L	30°S - 90°S	90°E - 0°E
M-Z	Not assigned	

3. Product Quality Control

3.1 Blank or invalid products

Full quality checks are performed on the LBR FDP products received at ESA/Earthnet from ground stations before encoding. Any 'blank' or 'invalid' products are not encoded, so all products disseminated on the WMO GTS are valid.

3.1.1 Definition of 'blank/invalid' for UAT data.

There is no explicit blank product indicator. For BUFR purposes, a product is a block of data for N sequential cells out of the complete orbit. A product is detected as blank if the three SST values (single-view, dual-view and mixed views) for all N cells are set to <0 (-1 indicates a missing value, any other negative value would be invalid as a SST). For the V5.xx encoder, N=150. (Ref.[A5])

3.1.2 Definition of 'blank/invalid' for URA data.

A product is detected as blank or invalid if Bit 2 (LSB=0) in the Product Confidence Data (PCD) is set. The PCD value is extracted from the SPH Field 1 (bytes 1-2). In addition, if the land flag (bit 13 (LSB=0) of the PCD from the SPH field 1) is set, the product is invalid. (Ref.[A1])

3.1.3 Definition of 'blank/invalid' for UWA data.

A product is detected as blank if all four I/Q values (MEAN I, MEAN Q, STDEV I, STDEV Q) are zero, or if Land flag in Bit 11 (LSB=0) in the Product Confidence Data (PCD) is set. These values are extracted from the SPH Fields 1,13-16 (bytes 1-2, 37-40, 41-44, 45-48 and 49-52). (Refs.[A1],[A2])

3.1.4 Definition of 'blank/invalid' for UWI data.

A product is detected as blank if Bit 5 (LSB=0) in the Product Confidence Data (PCD) is set. The PCD value is extracted from the SPH Field 1 (bytes 1-2). (Ref.[A1])

3.2 Product quality information

Product quality information such as the Product Confidence data is always included in the encoded files.

3.3 Transmission quality control

ERS BUFR encoded files are transmitted over the WMO GTS using standard TCP/IP (FTP) or X.25 protocols, so any transmission errors that may occur between ESA/ESRIN and the customer's node should be automatically corrected by the transmission protocol.

4. The WMO FM94 BUFR Format

4.1 Introduction

The products encoded at ESA/ESRIN into the WMO FM94 BUFR format are the following Fast Delivery Products:

- ATSR SADIST-2 ASST data ('UAT'),
- Radar Altimeter data ('URA'),
- AMI Wave mode data ('UWA') and
- AMI Wind Scatterometer ('UWI') data

4.2 File format

Each WMO FM94 BUFR encoded FDP product is transmitted from ESA/ESRIN as a continuous binary data stream. It consists of three parts:

- a WMO Header giving information that enables the file to be routed to customers over the WMO GTS,
- the FM94 BUFR encoded data (also referred to as a 'BUFR message'),
- a WMO Trailer which indicates the end of the file.

Note that a complete WMO FM94 BUFR encoded 'message' with header and trailer can also referred to as a 'WMO bulletin'.

4.3 Data types

Data is stored in the following formats:

I1	- 1 byte unsigned integer
I2	- 2 byte unsigned integer
I3	- 3 byte unsigned integer
A	- ASCII coded characters
B	- 1 byte value containing bit or flag information
I	- unsigned integer of variable bit length
b	- bit or flag data of variable length

Note that BUFR defines the LSB (Least Significant Bit/Byte) as the first in the encoded data bit stream (e.g. for flag bit data), but MSB first for whole-byte (multiples of eight bits) elsewhere in the message.

4.4 The WMO Header

31 bytes long. Applicable to all ERS products

The WMO header allows WMO GTS nodes to route a file in a table-driven way to defined destinations without knowing the file data contents. The header is a set of characters from the International Alphabet No. 5 (CCITT-IA5 - equivalent to ASCII) and takes the form:

<SOH><CR><CR><LF>*nnn*<CR><CR><LF>$T_1T_2A_1A_2ii$<SP>*cccc*<SP>*YYGGgg*<CR><CR><LF>

The elements of the WMO header are described in Table 4.1.

Note that the V5.xx BUFR encoder pre-pends four dummy <NUL> (zero value) bytes before the <SOH>. This is a requirement of the X.25 transmitter used by ESA/ESRIN for the backup direct link to Bracknell; these bytes are not transmitted or considered as part of the bulletin. In the following sections, data is referenced from the 'start of file'; this counting ignores any such leading null bytes, always starting at <SOH>.

Table 4.1: WMO Header Fields

Field Number	No of Bytes	Data Type	Byte Position in File	Description
1	1	A	1	'Start of Header' character (<SOH>), where:- <SOH> has byte value = 1 decimal (01 hex)
2	3	A	2 - 4	'Carriage Return' 'Carriage Return' 'Line Feed' characters (<CR><CR><LF>), where:- <CR> has byte value = 13 decimal (0D hex), <LF> has byte value = 10 decimal (0A hex)
3	3	A	5 - 7	'Message sequence number' generated by the encoding or routing centre (range 001 to 999).
4	3	A	8 - 10	Same as field 2.
5	6	A	11 - 16	Product definition field ($T_1T_2A_1A_2ii$). T_1 defines the Data Exchange format, where:- I = Observations in BUFR code. T_2 defines the Data Type, where:- O = Oceanographic, S = Surface or Sea level. A_1 defines the Data Sub-type, where:- W = Water waves (with T_2 = O), T = Sea surface temperature (with T_2 = O) X = Remotely-sensed (with T_2 = S), Z = Mixed reports (with T_2 = S). A_2 *defines* the Area Code (see Table 2.2). *ii* defines the Product type (see Table 4.2)
6	1	A	17	'Space' character (<SP>) where:- <SP> has byte value = 32 decimal (20 hex)
7	4	A	18-21	Source of the file *(cccc)* where:- EUSR = ESA/Frascati for all products.
8	1	A	22	Same as field 6.
9	6	A	23-28	Date/time (* See Note) of observation *(YYGGgg)* where:- *YY* = Day of month (01-31), *GG* = hour (00-23), *gg* = minute (00-59).
10	3	A	29-31	Same as field 2.

* Note: Because the GTS is intended for rapid data dissemination, the day/time parameter (*YYGGgg*) must indicate a data time within -23$^1/_2$ hours to +10 minutes from 'now' at the time of reception. Files with data times outside these limits will be rejected by the GTS message switching system. Test messages are coded with a recent time instead of data time - see Ref. [A3].

Combinations of the $T_1T_2A_1A_2ii$ *cccc* sequence that can occur for ERS-1 and ERS-2 bulletins for operational and test products are shown in Table 4.2. *Test messages are only generated for limited periods and are routed to limited recipients and are for end-to-end testing of software upgrades only.*

Table 4.2: Routing headers for ERS data

	T_1	T_2	A_1	A_2	*ii* ERS-1/ERS-2	*cccc*
Operational data:						
UWA:	I	O	W	A-L	05/55	EUSR
UWI:	I	S	X	A-L	08/58	EUSR
URA:	I	S	Z	A-L	09/59	EUSR
UAT:	I	O	T	A-L	23/53	EUSR
Test data:						
UWA:	I	O	W	A-L	65/75	EUSR
UWI:	I	S	X	A-L	68/78	EUSR
URA:	I	S	Z	A-L	69/79	EUSR
UAT:	I	O	T	A-L	63/73	EUSR

4.5 The WMO FM94 BUFR encoded data (BUFR message)

4.5.1 A brief general description of FM94 BUFR format

Each FDP file is encoded in WMO FM94 BUFR format into a BUFR message. A message consists of a continuous bit-stream of a sequence of octets (1 octet = 8 bits. While an octet will often be equivalent to a byte, the nature of the FM94 BUFR format means that the 8 bits of an octet can also be split between consecutive bytes – e.g. the least significant three bits of one byte and the most significant five bits of the next byte).

The format of a BUFR message is the same for all types of data and can consist of 6 sections (Sections 0 to 5), though Section 2 is optional and is not used in encoding ERS products. Section 0 has a fixed length of 8 octets and Section 5 has a fixed length of 4 octets. The first four and last four octets of a BUFR message are delimiters coded in the International Alphabet No. 5 (CCITT IA-5, equivalent to ASCII). The remaining Sections are binary and can be of variable length, though Section 1 is of fixed length for all ERS files, and Section 3 is of fixed length for each product type. The content of each BUFR section is summarised in Table 4.3.

The section lengths are expressed in bytes ("octets" in BUFR terms) and each section must always contain an even number of octets. If a section would normally contain an odd number of octets, it is padded out to an even length by appending an octet set to zero. This padding, if any, is included in the length of the section.

In the following paragraphs describing the BUFR encoded ERS products, octets are numbered 1, 2, 3... etc., starting at the beginning of each section. Bit positions within bytes or octets are numbered from 1 to 8 where bit 1 is the most significant bit and bit 8 the least significant bit (i.e. an octet with bit 8 set will have an integer value of 1).

Table 4.3: BUFR Section contents summary

Section number	Type of section	Brief description of contents
0	Start of BUFR message indicator	Characters "BUFR" Total length of message BUFR Edition number (currently 3)
1	Data identification	Length of section, identification of the data
2	For local use (optional) *	Length of section, additional items for local use
3	Data description	Length of section Number of data subsets Data compression flag Collection of descriptors which define the form and content of individual data elements
4	Data	Length of section, Binary encoded data
5	End of BUFR message identifier	Characters "7777"

* Section 2 is not used in the encoding of ERS products.

4.5.2 BUFR message contents for ERS products

Each BUFR message for ERS data contains five sections as outlined in 4.5.1. Section 5 is identical for all messages. Section 2 is not present for ERS data, and Sections 0, 1, 3 and 4 depend on the data and so differ from BUFR message to BUFR message. The contents of each section for each type of ERS product are defined in 4.5.2.1 to 4.5.2.5.

4.5.2.1 BUFR Section 0 (Start of BUFR Message Indicator)

8 bytes long. Applicable to all ERS products; defines the start of the BUFR encoded part of the data. The elements of the BUFR Section 0 are defined in Table 4.4.

Table 4.4: BUFR Section 0 (Start of BUFR Message) Fields

Field Number	No of Octets	Data Type	Byte Position in File	Description	Units
1	4	A	32 - 35	Start of the BUFR message indicator, characters '*BUFR*'	
2	3	I3	36-38	Total length of BUFR message (including Section 0)	octets
3	1	I1	39	BUFR Edition number (currently 3)	

4.5.2.2 BUFR Section 1 (ERS Product Identification Section)

18 bytes long. Applicable to all ERS products; defines the product that has been encoded. The elements of the BUFR Section 1 are defined in Table 4.5.

Table 4.5: BUFR Section 1 (ERS Product Identification) Fields

Field Number	No of Octets	Data Type	Byte Position in File	Description	Units
1	3	I3	40-42	Length of section (= 18)	octets
2	1	I1	43	BUFR Master table (= 0)	
3	1	I1	44	Originating/generating sub-centre (=code for ESA Ground Station from code table 0 01 034)	
4	1	I1	45	Originating/generating centre, from code table 0 01 033 (=210 : ESA/ESRIN for all products)	
5	1	I1	46	Update sequence number (=0 : original message)	
6	1	I1	47	Indicator of the use of BUFR section 2 (=0 : no Section 2 present)	
7	1	I1	48	Data category (=12 : Satellite data)	
8	1	I1	49	Data sub-category. (for ERS, =5 : UWA, =8 : UWI =9 : URA, =23 : UAT)	
9	1	I1	50	Version of master BUFR tables (= 7)	
10	1	I1	51	Version of local BUFR table (=0)	
11	1	I1	52	Year of century (1 - 100) * See note	
12	1	I1	53	Month (1 - 12) * See note	
13	1	I1	54	Day (1 - 31) * See note	
14	1	I1	55	Hour (0 - 23) * See note	
15	1	I1	56	Minute (0 - 59) * See note	
16	1	I1	57	0 (Pad byte)	

* Note: The Year/Month/Day/Hour/Minute is that most typical to the data in the product. For ERS, this is the date/time of the product (UWA, UWI) or of the first cell in the product (UAT, URA). The Year of Century is coded such that 1999 = 99, 2000 = 100, 2001 = 1, etc.

4.5.2.3 BUFR Section 3 (Data Description Section)

10 octets long. Applicable to all ERS products; defines how the data in the product has been encoded. The elements of the BUFR Section 3 are defined in Table 4.6.

Table 4.6: BUFR Section 3 (Data Description) Fields

Field Number	No of Octets	Data Type	Byte Position in File	Description	Units
1	3	I3	58-60	Length of section (=10)	octets
2	1	I1	61	Reserved (= 0)	
3	2	I2	62-63	Number of data subsets (observations) = 150 for UAT, = 77 for URA, = 1 for UWA, = 361 for UWI	
4	1	B	64	Data description flags = 192 (bits 1 and 2 set) for UAT, URA and UWI (to indicate that data was observed - as opposed to computed - and has been compressed) = 128 (bit 1 set) for UWA (to indicate that data was observed - as opposed to computed - and has not been compressed)	
5	2	I2	65-66	BUFR descriptor * See Note = 3 12 027 : UAT = 3 12 022 : URA = 3 12 025 : UWA = 3 12 021 : UWI	
6	1	I1	67	Pad character (=0)	

* Note: Values shown in 'FXY' format; see Appendix B for an overview of BUFR descriptors, Appendix C for lists of descriptors used for ERS products and Ref. [R3] for a full definition and lists of all accepted descriptors. In general, the number of descriptors present in Section 3 can be calculated from:
([Length of Section 3] - 8) / 2

4.5.2.4 BUFR Section 4 (Data Section)

Variable length. Applicable to all ERS products; contains the encoded data. The elements of the BUFR Section 4 are defined in Table 4.7.

Table 4.7: BUFR Section 4 (Data) Fields

Field Number	No of Octets	Data Type	Byte Position in File	Description	Units
1	3	I3	68-70	Length of section (variable)	octets
2	1	I1	71	Reserved byte (= 0)	
3	Variable	Binary bit stream	72 to (67 + Length of Section 4)	Binary data. See Section 5 and Annex C for a full description of the data values and sequences for the UAT, URA, UWA and UWI encoded products	

4.5.2.5 BUFR Section 5 (End of BUFR Message Indicator)

4 bytes long. Applicable to all ERS products defines the end of the BUFR encoded part of the data. The elements of the BUFR Section 5 are defined in Table 4.8.

Table 4.8: BUFR Section 5 (End of BUFR Message) Fields

Field Number	No of Octets	Data Type	Byte Position in File	Description	Units
1	4	A	(68 + Length of Section 4) to (72 + Length of Section 4)	End of the BUFR message indicator, characters '*7777*'	

4.6 The WMO Trailer

7 bytes long. Applicable to all ERS products. The WMO trailer indicates to the WMO GTS nodes the end of a bulletin. The trailer is a set of characters from the International Alphabet No. 5 (CCITT IA-5, - equivalent to ASCII) and takes the form:

<CR><CR><LF><CR><CR><LF><ETX>

The elements of the WMO trailer are described in Table 4.9.

Table 4.9: WMO Trailer Fields

Field Number	Number of Bytes	Data Type	Byte Position in File	Description
1	3	A	(73 + Length of Section 4)	'Carriage Return' 'Carriage Return' 'Line Feed' characters (<CR><CR><LF>), where:- <CR> has a byte value = 13 decimal (0D hex), <LF> has a byte value = 10 decimal (0A hex)
2	3	A	(76 + Length of Section 4)	Same as field 1.
3	1	A	(79 + Length of Section 4)	'End of Transmission' character (<ETX>), where:- <ETX> has a byte value = 3 decimal (03 hex)

4.7 Example of a complete file GTS as transmitted

In the previous sections, the contents of the encoded FDP data (the BUFR-encoded data stream), the WMO header used for routing the bulletin and the WMO trailer used to identify the end of the file have been defined. An example of a complete GTS file (a UWI product) is:

<SOH><CR><CR><LF> *nnn* <CR><CR><LF> I S X L 0 8 <SP> E U S R <SP>1 5 2 1 0 6 <CR><CR><LF> B U F R ... bufr sections 1-4 ... 7 7 7 7 <CR><CR><LF><CR><CR><LF><ETX>

where *nnn* and the sequences <*xx*> are defined in Sections 4.4 and 4.6.

Note that, since GTS bulletins are not guaranteed to be received in the same order as that transmitted by the originator, the end user must ensure that products are ordered correctly (possibly using the message sequence and/or date and time) before further processing. If only the geophysical data is to be extracted and cells are used individually, then the order of reception and storage of GTS bulletins probably does not matter.

Note also that the current maximum size of products that can be transmitted over the WMO GTS is officially 15Kbytes. However, no ESA-originated ERS product is expected to ever exceed 10Kbytes. The largest ESA products to be transmitted on the GTS are the UAT and UWI, which can exceptionally approach 9Kbytes for encoded products with compression, but which are generally no longer than 8Kbytes for UAT and 7Kbytes for UWI.

Uniquely, UAT (SADIST-2 ASST) products contain data for up to one complete orbit, typically 1300 to 1800 cells. In order to remain within the above GTS limit, and for compatibility with previous BUFR practice, each UAT BUFR message is a sub-product containing a sequence of 150 cells exactly. If the original UAT product does not contain a multiple of 150 cells, the last BUFR sub-product is padded with dummy cells indicating 'missing data' for all SST parameters.

5. Encoded Product Data Values

5.1 General information

Tables 5.1, 5.4, 5.8 and 5.15 list the parameters that appear in the encoded UAT, URA, UWA and UWI products respectively, together with the units used, the number of bits required for each parameter value and the reference value used by that parameter. The following points are relevant to these tables:

Uncompressed Data and Reference Value

- In order to minimise the size of the encoded files, parameter values are stored as differences between the actual parameter value and a **Reference value.** Reference values are not stored with the data (and therefore are not transmitted within a product) but are specified in the BUFR Tables used to encode or decode the product. These Tables are provided as ASCII files with the Encoder and Decoder software. *This is one of the reasons why it is essential that the supplier and receiver of BUFR encoded products use identical BUFR Tables.* Data stored in this format are known as **Uncompressed Data**.
- The '**Number of Bits/D**' column refers to the data width required after subtracting the Reference value. This is the maximum number of bits needed to represent a single value in a BUFR message and, like the Reference value, is specified in the BUFR Tables.

Compressed Data - Local reference Value

- A '**cell**' is a group of values relating to either a single observation or a logically connected set of observations; e.g. the latitude, longitude, fore, mid and aft beam data, surface wind data and product confidence flag constitutes a single 'cell' in the UWI product.
- It is possible to have multiple observations (cells) in a BUFR message. Depending on the parameter values within the observations, the encoding software may use, for each type of parameter, the dynamic minimum value found after subtracting the Reference value as a second, '**Local reference value**'. This Local reference value is again subtracted from each of this type of parameter value and the *Local Reference value, the bit width of the new differences and the actual new differences* (original parameter value-Reference value-Local reference value) are transmitted. The Local reference value and new data bit width are defined using special 16-bit BUFR descriptors (see Appendix A for further details and a fuller description of BUFR data compression). Data stored in this format is known as **Compressed Data.**
- The '**Number of Bits/C**' column refers to the estimated data width for compressed data and is an estimate of the minimum number of bits required to represent a single value in such a BUFR message. The actual number of bits required will depend on the range of values after the two reference values have been subtracted and will vary from product to product. As already mentioned, the actual data width is transmitted using a special 16-bit BUFR descriptor.
- As the BUFR scheme requires each observation to be self-contained; constant parameters must appear logically as part of each observation. However, these values are only transmitted once (only the Reference Value) then replicated, during decoding, for subsequent observations - hence the indicated **zero bits in the 'Number of Bits/C'** column after compression (see Appendix A for details)

The ERS BUFR encoded products UAT, URA and UWI contain compressed data; the UWA product, containing only a single observation, is uncompressed.

WARNING:

A set of BUFR Tables is required to both encode and decode products and, as noted above, it is essential that identical Tables be used in the encoding and decoding processes. These Tables are used for describing individual data elements (data width, units and scaling used, reference values etc.), data sequences, code and flag tables, etc. as well as holding codes for use in data compression and replication. The complete listings of element and sequence descriptors specific to ERS products are given in Appendix C.

5.2 Encoded UAT Product Data Values

Table 5.1 lists the parameters that appear in Section 4 of the encoded UAT SATIST-2 product, together with the data type, the units used, the number of bits required for each parameter value and the reference value used by that parameter. The points listed in Section 5.1 should be noted.

Note that BUFR is a bit oriented encoding scheme and is independent of any computer or file structure. Therefore the concept of a byte and byte boundaries is not used and only the start and end position of the data in a product can be defined (see Table 4.5).

Table 5.1: RAL UAT Product in FM94 BUFR Format

Field Number	Number of Bits D	Number of Bits C	Data Type	Descriptor F X Y	Description	Units/ Reference value
ERS header						
1	10	0	I	0 01 007	Satellite Identifier where:- =1 : ERS-1, =2 : ERS-2	code table / 0
2	14	0	I	0 25 060	Software Identifier	number / 0
3	8	0	b	0 01 033	Originating centre (= 210)	code table / 0
4	8	0	b	0 01 034	Ground station (=13 : Tromso)	code table (see Table 5.3) / 0
5	9	0		0 01 012	Satellite Track	*degrees* / 0
6	12	0	I	0 04 001	Year	*year* / 0
7	4	0	I	0 04 002	Month	*month* / 0
8	6	0	I	0 04 003	Day	*day* / 0
9	5	0	I	0 04 005	Hour	*hour* / 0
10	6	0	I	0 04 004	Minute	*minute* / 0
11	16	0	I	0 04 006	Second	*sec.* $*10^{-3}$ / 0
12	31	0	I	0 27 031	State vector: X location	*m* $*10^{-2}$ / -1073741824
13	31	0	I	0 28 031	State vector: Y location	*m* $*10^{-2}$/ -1073741824
14	31	0	I	0 10 031	State vector: Z location	*m* $*10^{-2}$/ -1073741824
15	31	0	I	0 01 041	State vector: X velocity	ms^{-1} $*10^{-5}$/ -1073741824
16	31	0	I	0 01 042	State vector: Y velocity	ms^{-1} $*10^{-5}$/ -1073741824
17	31	0	I	0 01 043	State vector: Z velocity	ms^{-1} $*10^{-5}$/ -1073741824
18	9	0	b	0 02 021	Satellite Instrument (= 128, i.e. bit 8 set)	flag table / 0
19	12	0	I	0 04 001	Year	*year* / 0
20	4	0	I	0 04 002	Month	*month* / 0
21	6	0	I	0 04 003	Day	*day* / 0
22	5	0	I	0 04 004	Hour	*hour* / 0
23	6	0	I	0 04 005	Minute	*minute* / 0
24	16	0	I	0 04 005	Second	*sec.* * 0^{-3} /0
25	15	9	I	0 05 002	Latitude	*deg.* $*10^{-2}$ / -9000
26	16	10	I	0 06 002	Longitude	*deg.* $*10^{-2}$ / -18000

Table 5.1: (continued) RAL UAT Product in FM94 BUFR Format

Field Number	Number of Bits D	Number of Bits C	Data Type	Descriptor F X Y	Description	Units/ Reference value
ATSR cell data						
Fields 27–32 are repeated 9 times (once for each 10-arcmin sub-cell) to fill fields 27-80 inclusive						
27	15	9	I	0 05 002	Latitude	*deg.* $*10^{-2}$ / -9000
28	16	10	I	0 06 002	Longitude	*deg.* $*10^{-2}$ / -18000
29	15	0	I	0 07 021	Incidence angle (nadir view) * See Note	*deg.* $*10^{-2}$ / -9000
30	12	7	I	0 12 061	Skin sea surface temperature (nadir view)	*K* $*10^{-1}$ / 0
31	15	0	I	0 07 021	Incidence angle (dual view) * See Note	*deg.* $*10^{-2}$ / -9000
32	12	7	I	0 12 061	Skin sea surface temperature (dual view)	*K* $*10^{-1}$ / 0
81	4	4	I	0 21 085	UAT across-track band number	number / 0
82	23	10	b	0 21 070	UAT SADIST-2 product confidence data	flag table (see Table 5.2) / 0

* Incidence angle values are set to zero for nadir view and 'missing' for dual view

Fields 1,2 and 6–17 are extracted from SADIST-2 header and Field 5 is calculated using Fields 6–17. Fields 3,4 and 18 are fixed constants (the ground station is assumed to be Tromso). Fields 19 to 82 inclusive constitute a 'cell' and are repeated 150 times per encoded product (strictly speaking, all the fields (1 to 82) constitute a cell and are repeated 150 times but, as fields 1 to 24 are identical in each cell, data compression reduces them to zero bits after their initial declaration in the first cell).

Table 5.2: UAT SADIST-2 Product Confidence Data (0 21 070)

Bit	Meaning when set
1–9	Nadir-only view SST retrieval used 3.7μm channel (one bit per 10-arcmin sub-cell)
10–18	Dual view SST retrieval used 3.7μm channel (one bit per 10-arcmin sub-cell)
19	Nadir view contains day-time data
20	Forward view contains day-time data
21	Record contains data acquired when ERS not in yaw-steering mode
22	Record contains data for which product confidence data show poor or unknown quality
All 23	Missing value

Table 5.3: Identifier of Product Generating Centre (0 01 034)

Value	Product generating centre
1	Kiruna
2	Fucino
3	Gatineau
4	Maspalomas
5	EECF (ESA ERS Central Facility)
6	Prince Albert
7-12	- not used
13	Tromso
14-254	- not used
255	missing

5.3 Encoded URA Product Data Values

Table 5.4 lists the parameters that appear in Section 4 of the encoded URA product, together with the data type, the units used, the number of bits required for each parameter value and the reference value used by that parameter. The points listed in Section 5.1 should be noted.

Note that BUFR is a bit oriented encoding scheme and is independent of any computer or file structure. As a result the concept of a byte and byte boundaries is not used and only the start and end position of the data in a product can be defined (see Table 4.5).

Table 5.4: ESA URA Product in FM94 BUFR Format

Field Number	Number of Bits D	Number of Bits C	Data Type	Descriptor F X Y	Description	Units/ Reference value
ERS header						
1	10	0	I	0 01 007	Satellite Identifier where:- =1 : ERS-1, =2 : ERS-2	code table / 0
2	14	0	I	0 25 060	Software Identifier	number / 0
3	8	0	b	0 01 033	Originating centre (= 210)	code table / 0
4	8	0	b	0 01 034	Ground station	code table (see Table 5.3) / 0
5	9	0		0 01 012	Satellite Track	*degrees* / 0
6	12	0	I	0 04 001	Year	*year* / 0
7	4	0	I	0 04 002	Month	*month* / 0
8	6	0	I	0 04 003	Day	*day* / 0
9	5	0	I	0 04 005	Hour	*hour* / 0
10	6	0	I	0 04 004	Minute	*minute* / 0
11	16	0	I	0 04 006	Second	*sec.* $*10^{-3}$ / 0
12	31	0	I	0 27 031	State vector: X location	*m* $*10^{-2}$ / -1073741824
13	31	0	I	0 28 031	State vector: Y location	*m* $*10^{-2}$/ -1073741824
14	31	0	I	0 10 031	State vector: Z location	*m* $*10^{-2}$/ -1073741824
15	31	0	I	0 01 041	State vector: X velocity	ms^{-1} $*10^{-5}$/ -1073741824
16	31	0	I	0 01 042	State vector: Y velocity	ms^{-1} $*10^{-5}$/ -1073741824
17	31	0	I	0 01 043	State vector: Z velocity	ms^{-1} $*10^{-5}$/ -1073741824
18	9	0	b	0 02 021	Satellite Instrument (= 64, i.e. bit 7 set)	flag table / 0
19	12	0	I	0 04 001	Year	*year* / 0
20	4	0	I	0 04 002	Month	*month* / 0
21	6	0	I	0 04 003	Day	*day* / 0
22	5	0	I	0 04 004	Hour	*hour* / 0
23	6	0	I	0 04 005	Minute	*minute* / 0
24	16	0	I	0 04 005	Second	*sec.* $*10^{-3}$ /0
25	15	9	I	0 05 002	Latitude	*deg.*$*10^{-2}$ / -9000
26	16	10	I	0 06 002	Longitude	*deg.*$*10^{-2}$/ -18000

Table 5.4: (continued) ESA URA Product in FM94 BUFR Format

Field Number	Number of Bits D	Number of Bits C	Data Type	Descriptor F X Y	Description	Units/ Reference value
Radar Altimeter cell data						
27	16	4	I	0 08 022	Number in average	number / 0
28	12	6	I	0 11 012	Wind Speed	$ms^{-1} * 10^{-1}$ / 0
29	12	6	I	0 11 050	Standard deviation of wind speed	$ms^{-1} * 10^{-1}$ / 0
30	13	8	I	0 22 070	Significant wave height	$m * 10^{-2}$ / 0
31	10	6	I	0 22 026	Standard deviation of SWH	$m * 10^{-2}$ / 0
32	28	8	I	0 07 001	Altitude (corrected)	$m * 10^{-2}$ / -400
33	16	8	I	0 10 050	Standard deviation of altitude	$m * 10^{-2}$ / 0
34	8	3	b	0 21 068	URA Product Confidence	flag table (see Table 5.5) / 0
35	16	8	I	0 21 071	Peakiness	number / 0
36	4	2	b	0 21 072	Calibration status	flag table (see Table 5.6) / 0
37	9	2	b	0 21 073	Instrument mode	flag table (see Table 5.7) / 0
38	14	12	I	0 21 077	Altitude correction (ionosphere)	$m * 10^{-3}$ / 0
39	9	7	I	0 21 078	Altitude correction (dry tropopause)	$m * 10^{-3}$ / 0
40	10	8	I	0 21 079	Altitude correction (wet tropopause)	$m * 10^{-3}$ / 2000
41	11	0	I	0 21 080	Altitude correction (calibration constant)	$m * 10^{-3}$ / 0
42	10	8	I	0 21 081	Open loop correction (HTL)	$m * 10^{-3}$ / 0
43	14	12	I	0 21 082	Open loop correction (AGC)	$dB * 10^{-3}$ / -3000
44	13	11	I	0 21 062	Backscatter	$dB * 10^{-2}$ / -5000
45	13	11	I	0 15 011	Electron density	$(log_{10}\ m^{-2})\ 10^{-3}$ / 14000

Fields 1 and 6-24 are normally extracted from the FDP Main Product Header (MPH) and Field 5 is extracted from the Specific Product Header (SPH). For the URA product, the date and time is from the individual data records. Fields 19 to 45 inclusive constitute a 'cell' and are repeated 77 times per encoded product (strictly speaking, all the fields (1 to 45) constitute a cell and are repeated 77 times but, as fields 1 to 18 are identical in each cell, data compression reduces them to zero bits after their initial declaration in the first cell).

Table 5.5: URA Product Confidence Data (0 21 068)

Bit	Meaning when set
1	Standard deviation wind speed outside MMCC limit
2	Standard deviation SWH outside MMCC limit
3	Standard deviation altitude outside MMCC limit
4	Mean peakiness outside MMCC limit
5	Frame checksum error detected
6	HTL time constant correction not performed
7	Not enough measurements (N < 10)
All 8	Missing value

1	Height error correction
2	Microwave sounder used for tropospheric correction
3	AGC output correction
All 4	Missing value

bit reset:	from open loop calibration
bit set:	default

Table 5.7: Altimeter Instrument Mode (0 21 073)

Bit	Meaning when set
1	Blank data record
2	Test
3	Calibration (closed loop)
4	BITE
5	Acquisition on Ice
6	Acquisition on Ocean
7	Tracking on Ice
8	Tracking on Ocean
All 9	Missing value

Table 5.6: Altimeter Calibration Status (0 21 072)

Bit	Status

5.4 Encoded UWA Product Data Values

Table 5.8 lists the parameters that appear in Section 4 of the encoded UWA (Version 2.0) product, together with the data type, the units used, the number of bits required for each parameter value and the reference value used by that parameter. The points listed in Section 5.1 should be noted.

Note that BUFR is a bit oriented encoding scheme and is independent of any computer or file structure. As a result the concept of a byte and byte boundaries is not used and only the start and end position of the data in a product can be defined (see Table 4.5).

Table 5.8: ESA UWA Product in FM94 BUFR Format

Field Number	Number of Bits D	Number of Bits C	Data Type	Descriptor F X Y	Description	Units/ Reference value
ERS header						
1	10	0	I	0 01 007	Satellite Identifier where:- =1 : ERS-1, =2 : ERS-2	code table / 0
2	14	0	I	0 25 060	Software Identifier	number / 0
3	8	0	b	0 01 033	Originating centre (= 210)	code table / 0
4	8	0	b	0 01 034	Ground station	code table (see Table 5.3) / 0
5	9	0		0 01 012	Satellite Track	*degrees* / 0
6	12	0	I	0 04 001	Year	*year* / 0
7	4	0	I	0 04 002	Month	*month* / 0
8	6	0	I	0 04 003	Day	*day* / 0
9	5	0	I	0 04 005	Hour	*hour* / 0
10	6	0	I	0 04 004	Minute	*minute* / 0
11	16	0	I	0 04 006	Second	*sec.* $*10^{-3}$ / 0
12	31	0	I	0 27 031	State vector: X location	*m* $*10^{-2}$ / -1073741824
13	31	0	I	0 28 031	State vector: Y location	*m* $*10^{-2}$/ -1073741824
14	31	0	I	0 10 031	State vector: Z location	*m* $*10^{-2}$/ -1073741824
15	31	0	I	0 01 041	State vector: X velocity	ms^{-1} $*10^{-5}$/ -1073741824
16	31	0	I	0 01 042	State vector: Y velocity	ms^{-1} $*10^{-5}$/ -1073741824
17	31	0	I	0 01 043	State vector: Z velocity	ms^{-1} $*10^{-5}$/ -1073741824
18	9	0	b	0 02 021	Satellite Instrument (= 16, i.e. bit 5 set)	flag table / 0
19	12	0	I	0 04 001	Year	*year* / 0
20	4	0	I	0 04 002	Month	*month* / 0
21	6	0	I	0 04 003	Day	*day* / 0
22	5	0	I	0 04 004	Hour	*hour* / 0
23	6	0	I	0 04 005	Minute	*minute* / 0
24	16	0	I	0 04 005	Second	*sec.* $*10^{-3}$ /0
25	15		I	0 05 002	Latitude	*deg.* $*10^{-2}$ / -9000
26	16		I	0 06 002	Longitude	*deg.* $*10^{-2}$ / -18000

Table 5.8: (continued) ESA UWA Product in FM94 BUFR Format

Field Number	Number of Bits D	Number of Bits C	Data Type	Descriptor F X Y	Description	Units/Reference value
AMI Wave Mode data						
27	4		b	0 02 104	Antenna polarisation	code table (see Table 5.9) / 0
28	7		I	0 02 121	Mean frequency	*GHz* $*10^{-1}$ / 0
29	4		I	0 02 113	No. of azimuth looks	number / 0
30	12		I	0 02 026	Range resolution	*m* $*10^{-2}$ / 0
31	12		I	0 02 027	Azimuth resolution	*m* $*10^{-2}$ / 0
32	10		I	0 02 111	Radar incidence angle	*deg.* $*10^{-1}$ / 0
33	9		I	0 02 140	SAR azimuth angle relative to satellite	*degrees* / 0
34	10		I	0 01 013	Radar platform velocity	$km.s^{-1} *10^{-2}$ / 0
35	15		I	0 07 001	Radar platform altitude	*km* $*10^{-1}$ / -400
36	4		b	0 25 010	Clutter treatment	code table (see Table 5.10) / 0
37	8		I	0 21 064	Clutter noise estimate	number / 0
38	31		I	0 15 015	Maximum spectrum component before normalisation	number / 0
39	3		b	0 29 002	Co-ordinate type	code table (see Table 5.11) / 0
40	3		b	0 21 076	Representation of intensities	code table (see Table 5.12) / 0
Fields 41 to 65 are repeated 12 times (to fill fields 41 to 340)						
41	168 *		I	0 06 030	Wave number (spectral)	$rad.m^{-1} *10^{-5}$ / 0
Fields 42 to 43 are repeated 12 times (to fill fields 42 to 65)						
42	1728 **			0 05 030	Direction (spectral)	*degrees* / 0
43	1152 ***			0 21 075	Spectral intensity	number / 0
341	12			0 21 066	UWA Product Confidence	flag table (see Table 5.13) / 0
342	4		b	0 08 060	Sample significance (range)	Code table (see Table 5.14) / 0
343	16		I	0 08 022	Number in sample (range)	number / 0
344	4		b	0 08 060	Sample significance (azimuth)	Code table (see Table 5.14) / 0
345	16		I	0 08 022	Number in sample (azimuth)	number / 0
346	12		I	0 25 014	Azimuth clutter cutoff	number / 0
347	31		I	0 22 101	Total energy (wavelengths>731m)	number / 0
348	14		I	0 22 097	Mean wavelength (wavelength > 731m)	*m* / 0
349	14		I	0 22 098	Wavelength spread (wavelength > 731m)	*m* / 0
350	9		I	0 22 099	Mean direction (wavelength > 731m)	*deg. True* / 0
351	9		I	0 22 100	Direction spread (wavelength > 731m)	*deg.* / 0

Notes:
* 168 = 12 wave numbers * 14 bits
** 1728 = 12 wave numbers * 12 directions * 12 bits
*** 1152 = 12 wave numbers * 12 directions * 8 bits

Note that the UWA product contains only one observation - albeit a two-dimensional one - so no dynamic compression is possible. Fields 1 and 6-24 are extracted from the FDP Main Product Header (MPH) and Field 5 is extracted from the Specific Product Header (SPH). Fields 27-37 and 342-351 are data required for best interpretation and comparison of spectral SAR data; fields 30-31 are taken from the SPH 'pixel separation' words and fields 37, 343, 345-351 are also extracted from the SPH. The remaining parameters are not contained in the ESA product specification so nominal values are entered for ERS-1 and ERS-2. Fields 41 and 42 define the spectral grid in terms of wave number and relative azimuthal direction. Again, these are not in the ESA data record specification, but are known and constant for this particular product. The actual number of grid points can be extracted from the repetition descriptors in the data description part of the encoded product (in BUFR section 3).

Table 5.9: Antenna Polarisation (0 02 104)

Code	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
6-14	Reserved
15	Missing value

Table 5.10: Clutter Treatment (0 25 010)

Code	Meaning
0	None
1	Map
2	Insertion of higher elevation data
3	Analysis of the fluctuating logarithm signal (clutter detection)
4	Extraction of the fluctuating part of the linear signal (clutter suppression)
5	Clutter suppression - Doppler
6	Multi-parameter analysis
7-14	Reserved
15	Missing value

Table 5.11: Co-ordinate Grid Type (0 29 002)

Code	Meaning
0	Cartesian
1	Polar
2	Other
3-6	Reserved
7	Missing value

Table 5.12: Representation of intensities (0 21 06)

Code	Meaning
0	linear
1	logarithmic (base e)
2	logarithmic (base 10)
3-6	Reserved
7	Missing value

Table 5.13: UWA Product Confidence Data (0 21 066)

Bit	Meaning when set
1	Processing equipment not working
2	Equipment problem (if bit 1 set): bit 2 reset: some problems with equipment bit 2 set: equipment failed
3	PRF code changed during image generation
4	Sampling window changed during image generation
5	Gain changed during image generation
6	Chirp replica exceeds specified values
7	Input data mean and standard deviation of I and Q out of range
8	Doppler centroid confidence >MMCC value
9	Doppler centroid absolute value >PRF/2
10	Doppler ambiguity confidence <MMCC value
11	Output data mean and standard deviation <= MMCC value
All 12	Missing value

Table 5.14: Sample Significance (0 08 060)

Code	Meaning
0	reserved
1	range
2	azimuth
3	horizontal
4	vertical
5-14	reserved
15	missing value

5.5 Encoded UWI Product Data Values

Table 5.15 lists the parameters that appear in Section 4 of the encoded UWI product, together with the data type, the units used, the number of bits required for each parameter value and the reference value used by that parameter. The points listed in Section 5.1 should be noted.

Note that BUFR is a bit oriented encoding scheme and is independent of any computer or file structure. As a result the concept of a byte and byte boundaries is not used and only the start and end position of the data in a product can be defined (see Table 4.5).

Table 5.15: ESA UWI Product in FM94 BUFR Format

Field Number	Number of Bits D	Number of Bits C	Data Type	Descriptor F X Y	Description	Units/ Reference value
ERS header						
1	10	0	I	0 01 007	Satellite Identifier where:- =1 : ERS-1, =2 : ERS-2	code table / 0
2	14	0	I	0 25 060	Software Identifier	number / 0
3	8	0	b	0 01 033	Originating centre (= 210)	code table / 0
4	8	0	b	0 01 034	Ground station	code table (see Table 5.3) / 0
5	9	0		0 01 012	Satellite Track	*degrees* / 0
6	12	0	I	0 04 001	Year	*year* / 0
7	4	0	I	0 04 002	Month	*month* / 0
8	6	0	I	0 04 003	Day	*day* / 0
9	5	0	I	0 04 005	Hour	*hour* / 0
10	6	0	I	0 04 004	Minute	*minute* / 0
11	16	0	I	0 04 006	Second	*sec.* $*10^{-3}$ / 0
12	31	0	I	0 27 031	State vector: X location	*m* $*10^{-2}$ / -1073741824
13	31	0	I	0 28 031	State vector: Y location	*m* $*10^{-2}$/ -1073741824
14	31	0	I	0 10 031	State vector: Z location	*m* $*10^{-2}$/ -1073741824
15	31	0	I	0 01 041	State vector: X velocity	ms^{-1} $*10^{-5}$/ -1073741824
16	31	0	I	0 01 042	State vector: Y velocity	ms^{-1} $*10^{-5}$/ -1073741824
17	31	0	I	0 01 043	State vector: Z velocity	ms^{-1} $*10^{-5}$/ -1073741824
18	9	0	b	0 02 021	Satellite Instrument (= 8, i.e. bit 4 set)	flag table / 0
19	12	0	I	0 04 001	Year	*year* / 0
20	4	0	I	0 04 002	Month	*month* / 0
21	6	0	I	0 04 003	Day	*day* / 0
22	5	0	I	0 04 004	Hour	*hour* / 0
23	6	0	I	0 04 005	Minute	*minute* / 0
24	16	0	I	0 04 005	Second	*sec.* $*10^{-3}$ /0
25	15	9	I	0 05 002	Latitude	*deg.* $*10^{-2}$ / -9000
26	16	10	I	0 06 002	Longitude	*deg.* $*10^{-2}$ / -18000

Table 5.15: (continued) ESA UWI Product in FM94 BUFR Format

Field Number	Number of Bits D	Number of Bits C	Data Type	Descriptor F X Y	Description	Units/ Reference value
AMI Wind Mode (Scatterometer) cell data						
Fields 27 to 31 are repeated 3 times for Fore, Mid and Aft beam data:						
27	10	9	I	0 02 111	Radar incidence angle	$deg.*10^{-1}$ / 0
28	12	8	I	0 02 112	Radar look angle	$deg.*10^{-1}$ / 0
29	13	11	I	0 21 062	Backscatter (σ°)	$dB*10^{-2}$ / -5000
30	10	4	I	0 21 063	Noise figure (*Kp*)	percent $*10^{-1}$ / 0
31	8	3	I	0 21 065	Missing packet counter	number / -127
42	12	6	I	0 11 012	Wind speed at 10m	$ms^{-1}*10^{-1}$ / 0
43	9	6	I	0 11 011	Wind direction at 10m	*degrees* / 0
44	13	4	b	0 21 067	UWI Product Confidence	flag table (see Table 5.16) / 0

Fields 1 and 6-24 are extracted from the FDP Main Product Header (MPH) and Field 5 is extracted from the Specific Product Header (SPH). Fields 25 to 44 inclusive constitute a 'cell' and are repeated 361 times per encoded product (strictly speaking, all the fields (1 to 44) constitute a cell and are repeated 361 times but, as fields 1 to 24 are identical in each cell, data compression reduces them to zero bits after their initial declaration in the first cell).

Table 5.16: UWI Product Confidence Data (0 21 067)

Bit	Meaning when set
1	No forebeam calculation
2	No midbeam calculation
3	No aftbeam calculation
4	Forebeam arcing detected
5	Midbeam arcing detected
6	Aftbeam arcing detected
7	Any beam K_p above or equal to threshold
8	Land (any land in cell footprint)
9	Autonomous ambiguity removal not used
10	Meteorological background not used
11	Minimum residual exceeded threshold
12	Frame checksum error detected
All 13	Missing value

6. Product File Sizes

6.1 General Notes

The indicated total number of bytes is likely to be a typical value for the majority of products. Experience with the UWI product indicates a normal range of 5-7 Kbytes per product, with an average close to the 6.4 Kbytes estimated in Table 6.4. Other products confirm that these estimates are realistic.

The **Uncompressed data** value gives the maximum size and the **Compressed data** value an estimate of the minimum size that can be expected for items/products. An explanation of uncompressed and compressed data formats is given in Section 5.1; see also Appendix A. The total Kbytes per product and per orbit include overheads and are for the maximum number of products per orbit.

Blank or invalid FDPs (e.g. wholly over land) are not encoded; the average number of products per orbit for these products may therefore fewer than indicated.

6.2 The UAT Product

Fields 1-24 occur once only, as a product header, so they are not counted in the "Total bits per cell" figure.

Table 6.1: Cell and Product Sizes for UAT Products

	Uncompressed data	Compressed data
Total bits per cell:	1165	330
Total bytes per cell:	146	42
Total bytes per 500 cells:	21900	6300
Number of bytes of overhead:	121	121
Total Kbytes per product (150 cells):	21.5	6.3
Total Kbytes per orbit (10 products):	215	63

6.3 The URA Product

Fields 1-18 occur once only, as a product header, so they are not counted in the "Total bits per cell" figure. As Fields 19-24 refer to individual cells, they count towards the total bits per cell.

Table 6.2: Cell and Product Sizes for URA Products

	Uncompressed data	Compressed data
Total bits per cell:	318	166
Total bytes per cell:	40	21
Total bytes per 77 cells:	3080	1617
Number of bytes of overhead:	115	115
Total Kbytes per product (77 cells):	3.2	1.7
Total Kbytes per orbit (80 products):	256	139

6.4 The UWA Product

As this product only contains a single observation (cell), Fields 1-24 *are* included in the "Total bits per cell" figure. Also, as this product only contains a single observation (cell), there is no possibility of compressing the data by use of the BUFR replication technique. Therefore, there is no "Compressed data" column.

Table 6.3: Cell and Product Sizes for UWA Products

	Uncompressed data
Total bits per cell:	3694
Total bytes per cell:	462
Total bytes per product:	462
Number of bytes of overhead:	78
Total Kbytes per product:	0.54
Total Kbytes per orbit (150 products):	80

6.5 The UWI Product

Fields 1-24 occur once only, as a product header, so they are not counted in the "Total bits per cell" figure.

Table 6.4: Cell and Product Sizes for UWI Products

	Uncompressed data	Compressed data
Total bits per cell:	224	140
Total bytes per cell:	28	18
Total bytes per 19*19 cells:	10108	6498
Number of bytes of overhead:	121	121
Total Kbytes per product (19 *19 cells):	10.2	6.6
Total Kbytes per orbit (70 products):	716	463

Appendix A – BUFR Data Compression

Where a number of data sub-sets (or cells) with identical descriptions are stored together in a BUFR message, data compression may be used, element by element. The BUFR data compression method is particularly effective where variations of each element between the sub-sets is small. For each element, the range is examined, and the minimum extracted. Corresponding elements for each data sub-set are represented in terms of differences from these minima. For example, consider the following group of identically defined data sub-sets:

	station number	station height	pressure	temperature	dew point
sub-set 1	101	296	10132	122	110
sub-set 2	125	291	10122	121	110
sub-set 3	127	310	10050	105	099
sub-set 4	136	295	10119	110	102
sub-set 5	138	350	10055	095	089
sub-set 6	141	325	10075	101	091

Extraction of the minimum value of each element gives:

101	291	10050	095	089

If each value is now represented as the difference from these minima, a set of "increments" is obtained as follows:

0	5	82	27	21
24	0	72	26	21
26	19	0	10	10
35	4	69	15	13
37	59	5	0	0
40	34	25	6	2

By representing this reduced set of values, fewer bits are required to represent each value. This is achieved in the actual data as

min (element 1),	data width of increments (element 1),	inc1,	inc2,	...etc.
min (element2),	data width of increments (element 2),	inc1,	inc2,	...etc.
.	.	.	.	.
min (element n),	data width of increments (element n),	inc1,	inc2,	...etc.

where inc1, inc2, etc. are the increments, each represented in the data width given.
The minima of each element are the Local Reference values and these and the Data widths of the increments are specified using special 16-bit BUFR descriptors as follows:-

Local Reference value - The most significant 8 bits have a value of -125 and the least significant 8 bits the new local reference value,

Data width of the increments - The most significant eight bits have a value of -127 and the least significant eight bits the (difference between the old and new data widths - 128). This allows for increasing as well as decreasing the data width. (Associated with a change of data width there is frequently a change in scale. This is defined by a 16-bit BUFR descriptor whose most significant eight bits are set to -126 and least significant eight bits define the (change in scale-128)).

These values appear in BUFR sequences defined in BUFR Table D and are used to rescale data from the standard settings defined in BUFR Table B to the values defined in Tables 5.1, 5.4, 5.8 and 5.15 in this document.

The algorithm for accomplishing data compression follows:-

i) Start with the set of n values of the first element (with the appropriate table reference value R already subtracted out) of each of the n sub-sets of the BUFR message.
ii) Scan the set and find the minimum value therein: this value is called the local reference value, Ro.
iii) Subtract the local reference value from each of the n values giving a set of increments, I.
iv) Determine the number of bits necessary to contain an unsigned integer value equal to the largest of the increments plus 1, Wi.
v) Repeat the process for values of the remaining elements in the BUFR message.

The original values V can be recovered by

$$V = R + Ro + I$$

R = Table reference value
Ro = Local reference value
I = Increment

Missing values in the original data, providing that not all values are missing values, are to be ignored when finding the local reference value (step ii), and calculating the increments (step iii).

Local reference values are represented according to the units, scale, reference value and data width defined for the corresponding data element.

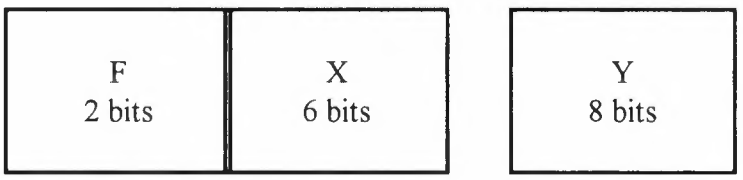
Missing values are indicated by increment values of all ones.

A set of identical values is represented by entering the single value for the set as the local reference value, the data width for the increments as zero, and omitting the set of increments. A set of missing values is represented by entering the missing value (field of ones) as the local reference value, the width for the increments as zero, and omitting the set of increments. This is summed up in the following table:

Local Ref. (Ro)	Values (Wi)	Increments (I)	Meaning
all ones	zero	omitted	set of missing values
not all ones	zero	omitted	set of identical values (V=R+R0)
not all ones	not zero	present	set of non-identical values (V=R+Ro+I)
not all ones	not zero	all ones	value corresponding to this increment is missing

Appendix B – BUFR Descriptor Overview

A BUFR descriptor is a coded number, which is used to describe the data within the BUFR message. Each descriptor occupies 2 octets and contains 3 parts:



If F = 0, the descriptor is an *element descriptor*. The values of X and Y refer directly to a single entry in BUFR Table B, X indicating the class and Y the entry within the class.

If F = 1, the descriptor is a *replication descriptor*, defining the replication data description operator. The values of X and Y define the scope of the operator and the number of replications, respectively. If Y = 0, delayed replication is defined; the next element descriptor will define a data item giving the number of replications. This descriptor may also indicate (by its value of Y) that the following datum is to be replicated together with the following descriptor.

If F = 2, the descriptor is an *operator descriptor*. The value of X indicates an operation, defined in BUFR Table C; the meaning of Y depends on the operation. Examples of operations are temporary modifications to the Table B element bit width, reference value or scaling and defining associated data such as quality or statistical information.

If F = 3, the descriptor is a *sequence descriptor*. The values of X and Y refer directly to a single entry in BUFR Table D. Each entry in Table D contains a list of element descriptors, data description operators, and/or other sequence descriptors. A sequence descriptor is defined to be equivalent to the corresponding list of descriptors at the Table D entry.

See Ref.[R3] for a full list of the current official list of 'global' descriptors (i.e. those approved for international exchange of data in BUFR FM94). Local descriptors may be defined by the user, but BUFR messages using them should not be exchanged with other users unless exactly the same local descriptors have been defined by both parties in Table B and possibly Table D.

Appendix C – BUFR Descriptors for ERS Products

Table C1: BUFR element descriptors for ERS products from BUFR Table B

Descriptor	Name	Scale	Reference	Width	Units
0 01 041	Velocity of platform, X	5	-1073741824	31	ms^{-1}
0 01 042	Velocity of platform, Y	5	-1073741824	31	ms^{-1}
0 01 043	Velocity of platform, Z	5	-1073741824	31	ms^{-1}
0 02 111	Radar incidence angle	1	0	10	*deg*
0 02 112	Radar look angle (*clockwise from North*)	1	0	12	*deg*
0 02 140	SAR azimuth angle (*anti-clockwise from satellite heading vector*)	0	0	9	*deg*
0 08 022	Number in sample	0	0	16	number
0 08 060	Sample significance	0	0	4	table
0 15 011	$\log_e$ of integrated electron density	3	14000	13	$\log_e m^{-2}$
0 15 015	Maximum spectral composition before normalisation	0	0	31	number
0 21 062	Radar backscatter	2	-5000	13	*dB*
0 21 063	Noise figure	1	0	10	%
0 21 064	Clutter noise estimate	0	0	8	number
0 21 065	Missing packet counter	0	-127	8	number
0 21 066	UWA Product confidence	0	0	12	flag table
0 21 067	UWI Product confidence	0	0	13	flag table
0 21 068	URA Product confidence	0	0	8	flag table
0 21 070	UAT Product confidence	0	0	23	flag table
0 21 071	Peakiness	0	0	16	number
0 21 072	Altimeter calibration status	0	0	4	flag table
0 21 073	Altimeter instrument mode	0	0	9	flag table
0 21 075	Spectral intensity	0	0	8	number
0 21 076	Representation of int.	0	0	3	code table
0 21 077	Altitude correction. (ionosphere)	3	0	14	*m*
0 21 078	Altitude correction (dry troposphere)	3	0	9	*m*
0 21 079	Altitude correction (wet troposphere)	3	2000	10	*m*
0 21 080	Altitude correction (calibration constant)	3	0	11	*m*
0 21 081	Open loop correction (HTL)	3	0	10	*m*
0 21 082	Open loop correction (AGC)	3	-3000	14	*dB*
0 21 085	UAT Across-track band no.	0	0	4	number
0 22 026	Standard deviation. SWH	2	0	10	*m*
0 22 097	Mean wavelength (wavelength>731m)	0	0	14	*m*
0 22 098	Wavelength spread (wavelength>731m)	0	0	14	*m*
0 22 099	Mean direction (wavelength>731m)	0	0	9	*deg True*
0 22 100	Direction spread (wavelength>731m)	0	0	9	*deg*
0 22 101	Total energy (wavelength>731m)	0	0	31	number
0 25 014	Azimuth clutter cutoff	0	0	12	number
0 10 031	Location of platform, Z	2	-1073741824	31	*m*
0 27 031	Location of platform, X	2	-1073741824	31	*m*
0 28 031	Location of platform, Y	2	-1073741824	31	*m*

Tables C2-C5 show the sequence of descriptors defined by the top-level sequence descriptor as defined in BUFR Table D, and which is inserted into the BUFR message at Section 3.

Table C2: BUFR main sequence for UAT product from BUFR Table D

Descriptor	Expansion	Meaning
3 12 027	3 01 047	Product header
	1 05 009	Repeat next 5 descriptors 9 times
	3 01 023	Location (latitude, longitude)
	0 07 021	Incidence angle
	0 12 061	Skin sea surface temperature
	0 07 021	Incidence angle
	0 12 061	Skin sea surface temperature
	0 21 085	UAT Across-track band number
	0 21 070	UAT SADIST-2 product confidence data

Table C3: BUFR man sequence for URA product from BUFR Table D

Descriptor	Expansion	Meaning
312022	3 01 047	Product header
	0 08 022	Number in average
	0 11 012	Wind speed
	0 11 050	Standard deviation of wind speed
	0 22 070	Altimeter significant wave height
	0 22 026	Standard deviation SWH
	3 12 041	Radar Altitude (corrected)
	0 10 050	Standard deviation altitude
	0 21 068	URA Product confidence data
	0 21 071	Peakiness
	0 21 072	Altimeter calibration status
	0 21 073	Altimeter instrument mode
	3 12 042	Altitude corrections
	0 21 062	Radar backscatter
	0 15 011	(log of) Integrated electron density

Table C4: BUFR main sequence for UWA product from BUFR Table D

Descriptor	Expansion	Meaning
3 12 025	3 12 019	Wave scatterometer product (with change...)
	0 08 060	Sample significance (range)
	0 08 022	Number in sample (range)
	0 08 060	Sample significance (azimuth)
	0 08 022	Number in sample (azimuth)
	0 25 014	Azimuth clutter cut-off
	0 22 101	Total energy (wavelengths > 731m)
	0 22 097	Mean wavelength (wavelength > 731m)
	0 22 098	Wavelength spread (wavelength > 731m)
	0 22 099	Mean direction (wavelength > 731m)
	0 22 100	Direction spread (wavelength > 731m)

Table C5: BUFR main sequence for UWI product from BUFR Table D

Descriptor	Expansion	Meaning
3 12 021	3 01 047	Product header
	1 01 003	Repeat next descriptor 3 times
	3 01 049	Radar beam data
	0 11 012	Wind speed at 10m
	0 11 011	Wind direction at 10m
	0 21 067	UWI Product confidence data

Tables C2-C5 above show the expanded sequences for each main sequence in BUFR Table. Some of these descriptors are themselves sequence descriptors. Tables C6-C14 show those further expansions, specific to ERS products only, as defined in BUFR Table D.

Table C6: ERS Product header

Descriptor	Expansion	Meaning
3 01 047	0 01 007	Satellite Identifier
	0 25 060	Software Identifier
	0 01 033	Identifier of product generating centre
	0 01 034	ESA/ESRIN ground station identifier
	0 01 012	Satellite track
	3 01 045	Satellite location and velocity
	0 02 021	Satellite instrument data used in processing
	3 01 011	Date (Year, Month, Day)
	0 04 004	Hour
	0 04 005	Minute
	2 01 138	Change width to 16 bits
	2 02 131	Change scale to 3
	0 04 006	Second
	2 01 000	Change width back to Table B
	2 02 000	Change scale back to Table B
	3 01 023	Location (Latitude, Longitude)

Table C7: Satellite location and velocity

Descriptor	Expansion	Meaning
3 01 045	3 01 011	Year, Month, Day
	0 04 004	Hour
	0 04 005	Minute
	2 01 138	Change width to 16 bits
	2 02 131	Change scale to 3
	0 04 006	Second
	2 01 000	Change width back to Table B
	2 02 000	Change scale back to Table B
	3 04 030	Location relative to Earth's centre
	3 04 031	Velocity relative to Earth's centre

Table C8: Location of platform

Descriptor	Expansion	Meaning
3 04 030	0 27 031	X-location from Earth's centre in direction 0° E
	0 28 031	Y-location from Earth's centre in direction 90° E
	0 10 031	Z-location from Earth's centre in direction North Pole

Table C9: Velocity of platform

Descriptor	Expansion	Meaning
3 04 031	0 01 041	X-velocity from Earth's centre in direction 0° E
	0 01 042	Y-velocity from Earth's centre in direction 90° E
	0 01 043	Z-velocity from Earth's centre in direction North Pole

Table C10: Radar Altitude

Descriptor	Expansion	Meaning
3 12 041	2 01 141	Change width to 28 bits
	2 02 130	Change scale to 2
	0 07 001	Altitude
	2 01 000	Change width back to Table B
	2 02 000	Change scale back to Table B

Table C11: Altitude Corrections

Descriptor	Expansion	Meaning
3 12 042	0 21 077	Altitude correction, ionosphere
	0 21 078	Altitude correction, dry troposphere
	0 21 079	Altitude correction, wet troposphere
	0 21 080	Altitude correction, calibration constant
	0 21 081	Open loop HTL calibration correction
	0 21 082	Open loop AGC calibration correction

Table C12: Wave scatterometer product (with width change for wave number (spectral))

Descriptor	Expansion	Meaning
3 12 019	3 01 047	Product header
	3 01 048	Radar parameters
	0 15 015	Maximum spectral composition before normalisation
	0 29 002	Coordinate type
	0 21 076	Representation of intensities
	1 06 012	Repeat next 6 descriptors 12 times
	2 01 129	Change width to 14 bits
	0 06 030	Wave number (spectral)
	2 01 000	Change width back to Table B
	1 02 012	Repeat next 2 descriptors 12 times
	0 05 030	Direction (spectral)
	0 21 075	Image spectral intensity
	0 21 066	UWA Product confidence data

Table C13: Radar parameters

Descriptor	Expansion	Meaning
3 01 048	0 02 104	Antenna polarisation
	0 02 121	Mean frequency
	0 02 113	Number of azimuth looks
	0 02 026	Cross-track (range) resolution
	0 02 027	Along-track (azimuth) resolution
	0 02 111	Radar incidence angle
	0 02 140	SAR azimuth angle
	2 02 127	Change scale to -1
	0 01 013	Radar platform velocity
	2 02 126	Change scale to -2
	0 07 001	Radar platform altitude
	2 02 000	Change scale to Table B
	0 25 010	Clutter treatment
	0 21 064	Background noise level

Table C14: Radar beam data

Descriptor	Expansion	Meaning
3 01 049	0 02 111	Radar incidence angle
	0 02 112	Radar look angle
	0 21 062	Backscatter
	0 21 063	Noise figure
	0 21 065	Missing packet counter