

SMOS NRT BUFR specification

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- 2- Deimos space
- 3- INDRA
- 4- European Space Agency (ESA)

Change Record:

| | DATE | CHANGE STATUS |
|-----|------------|--|
| 1.0 | 14/03/2008 | Document prepared by ECMWF |
| 1.1 | 26/03/2008 | Incorporates comments from M. Zapáta Gonzales and file naming convention. Includes a section on BUFR encoding |
| 1.2 | 04/04/2008 | File naming convention updated according to INDRA's request to include sensing stop time in the file name. |
| 1.3 | 29/05/2008 | Clarifications from DEIMOS (Andrés Canales) concerning the file naming convention. |
| 1.4 | 07/08/2008 | Correction of scale and data width of Faraday and Azimuth angles (comment by Andres Canales and Antonio Gutiérrez). |
| 1.5 | 09/09/2008 | Update of the TEC element name according to WMO document updated by Milan Dragosavac. Spelling correction on the "Radiometric accuracy name". |
| 1.6 | 27/10/2008 | WMO update on references 001024, 007011, 025144, 002098 which become 001124, 007012, 025174, 002099 respectively. |
| 1.7 | 07/11/2008 | Modification of the overall quality corresponding parameters. The overall quality refers to the Product_Confidence of the SO-TN-IDR-005 document of the Main Product Header (instead of to the 'Overall_quality' of the SO-ID-DMS-GS-002 document as it was indicated in version 1.6). |
| 1.8 | 10/11/2008 | Clarification of the relation between the TB fields (012080, 012081) and the polarisation information code table (R. Crapolicchio). Calibration degradation and multiple degradation included in the overall quality code table (reserved codes 5 and 6). |
| 1.9 | 18/03/2009 | Compression setting and WMO version table clarified |
| 2.0 | 06/02/2012 | Upgrades in the information flag table, in particular in the RFI Flag |
| 3.0 | 02/04/2015 | Update the flags information to processor V620 in agreement with the NRT Product Specification document (SO-ID-DMS-GS-0002 v4.1) |

This document provides the BUFR specification for the Level 1c SMOS NRT products. It was prepared by ECMWF with input from Deimos and ESA. The SMOS NRT BUFR specification is based on both:

- WMO data representation and codes,
- SMOS NRT product format specification provided by DEIMOS in the document SO-ID-DMS-GS-0002 v4.1.

The SMOS BUFR specification has been validated by WMO at the end of October 2008.

The following table indicates the BUFR message content. Each BUFR message contains the data describing one snapshot and data for each of its pixels. One BUFR file may contain several BUFR messages.

For each field both the DEIMOS and WMO references are indicated. In WMO Common Tables driven codes contain a sequence of data descriptors, which is like a set of "pointers" towards elements in predefined and internationally agreed tables (stored in the official WMO Manual on Codes). By definition these descriptors are six digits reference numbers as defined in the WMO Common Codes Tables. The list of new Table entries and corresponding codes will be proposed to WMO meeting of the Expert Team on Data Representation and Codes (ET/DRC).

In BUFR most meteorological or oceanographic parameters are represented in Standard International (SI) units such as meters or degrees Kelvin. However, the data may also be Numeric (e.g. a WMO block number), or character. Furthermore, the units may also refer to a code or flag table following the WMO Manual On Codes. The scale factor is the exponent of the power of 10 by which the value of the element has to be multiplied prior to encoding. The reference value is a number to be subtracted from the data after multiplication by the scale factor (if any) but before encoding in order to produce a non negative value in all cases. It corresponds to the minimum possible value of the field after scaling. The data width is a count of how many bits the largest possible value of an individual data item occupies, after multiplication with the scale factor and subtraction of the reference value.

| Line | Deimos Table SO-ID-DMS-GS-002 | WMO Table Reference (descriptor) | Element name | BUFR | | | |
|------|---|----------------------------------|---|------------|-------|------------|------------|
| | | | | Unit | Scale | Ref. value | Data width |
| 1 | Fixed value = 046 | 001007 | Satellite identifier | Code table | 0 | 0 | 10 |
| 2 | Fixed value = 176 | 002019 | Instrument type | Code table | 0 | 0 | 11 |
| 3 | Table 12 field #3 | 001144 | Snapshot identifier | Numeric | 0 | 0 | 31 |
| 4 | Table 13/14 field #2 | 001124 | Grid point identifier | Numeric | 0 | 0 | 24 |
| 5 | TBD | 030010 | Number of grid points | Numeric | 0 | 0 | 13 |
| 6 | Table 13/14 field #2 | 004001 | Year | Year | 0 | 0 | 12 |
| 7 | Table 13/14 field #2 | 004002 | Month | Month | 0 | 0 | 4 |
| 8 | Table 13/14 field #2 | 004003 | Day | Day | 0 | 0 | 6 |
| 9 | Table 13/14 field #2 | 004004 | Hour | Hour | 0 | 0 | 5 |
| 10 | Table 13/14 field #2 | 004005 | Minute | Minute | 0 | 0 | 6 |
| 11 | Table 13/14 field #2 | 004006 | Second | Second | 0 | 0 | 6 |
| 12 | Table 13/14 field #3 | 005001 | Latitude | Degrees | 5 | -9000000 | 25 |
| 13 | Table 13/14 field #4 | 006001 | Longitude | Degrees | 5 | -18000000 | 26 |
| 14 | Table 13/14 field #5 | 007012 | Grid point altitude | M | 2 | -50000 | 20 |
| 15 | Table 12 field #16 | 015012 | Total electron count per square meter | 1/M**2 | -16 | 0 | 6 |
| 16 | Table 12 field #22 | 012165 | Direct sun brightness temperature | K | 0 | 0 | 23 |
| 17 | Table 12 field #23 | 012166 | Snapshot accuracy | K | 1 | -4000 | 13 |
| 18 | Table 12 field #24 | 012167 | Radiometric accuracy (pure polarisation) | K | 1 | 0 | 9 |
| 19 | Table 12 field # 24 | 012168 | Radiometric accuracy (cross polarisation) | K | 1 | 0 | 9 |
| 20 | Table 13/14 field #16 | 027010 | Footprint axis 1 | M | -1 | 0 | 14 |
| 21 | Table 13/14 field #17 | 028010 | Footprint axis 2 | M | -1 | 0 | 14 |
| 22 | Table 13/14 field #8 | 002099 | Polarisation | Code table | 0 | 0 | 3 |
| 23 | Table 13/14 field #6 | 013048 | Water fraction | % | 1 | 0 | 10 |
| 24 | Table 13/14 field #11 | 025081 | Incidence angle | Degree | 3 | 0 | 17 |
| 25 | Table 13/14 field #12 | 025082 | Azimuth angle | Degree | 3 | 0 | 19 |
| 26 | Table 13/14 field #13 | 025083 | Faraday rotational angle | Degree | 3 | 0 | 19 |
| 27 | Table 13/14 field #14 | 025084 | Geometric rotational angle | Degree | 5 | 0 | 26 |
| 28 | Table 13/14 field #9a | 012080 | Brightness temperature real part | K | 2 | -10000 | 16 |
| 29 | Table 13/14 field #9b | 012081 | Brightness temperature imaginary part | K | 2 | -10000 | 16 |
| 30 | Table 13/14 field #10 | 012082 | Pixel radiometric accuracy | K | 2 | 0 | 12 |
| 31 | Table 13/14 field #8 | 025174 | SMOS information flag | Flag table | 0 | 0 | 14 |
| 32 | Table 4-1, field #23 (Doc. SO-TN-IDR-GS-0005) | 033028 | Snapshot Overall Quality | Code table | 0 | 0 | 3 |

Table: SMOS BUFR message content

The overall unexpanded date WMO descriptor is 301011. Its expanded descriptors are defined in WMO Common Code Table and used here: 004001 (year), 004002 (month), 004003 (day). The unexpanded time of observation's descriptor is 301012. It encompasses the expanded descriptors used here: 004004 (Hour) and 004005 (Minutes). The unexpanded latitude-longitude descriptor is 301021 (high accuracy). The expanded descriptors 005001 (latitude) and 005001 (longitude) are used respectively.

New WMO entries

For the purpose of SMOS data encoding, the following new entries have been proposed by M. Dragosavac to WMO Common Codes Tables (WMO Table B). These new entries have been validated by the WMO:

| | | | | |
|----|--------|---|--------|-----------------|
| 1 | 001007 | SATELLITE IDENTIFIER | | CODE TABLE 1007 |
| 2 | 002019 | SATELLITE INSTRUMENT TYPE | | CODE TABLE 2019 |
| 3 | 001144 | SNAPSHOT IDENTIFIER (VAL) | | NUMERIC |
| 4 | 001124 | GRID POINT IDENTIFIER (VAL) | | NUMERIC |
| 5 | 030010 | NUMBER OF GRID POINTS (VAL) | | NUMERIC |
| 14 | 007012 | GRID POINT ALTITUDE (VAL) | | M |
| 15 | 015012 | TOTAL ELECTRON COUNT (VAL) | | 1/M**2 |
| 16 | 012165 | DIRECT SUN BRIGHTNESS TEMPERATURE (VAL) | | K |
| 17 | 012166 | SNAPSHOT ACCURACY (VAL) | | K |
| 18 | 012167 | RADIOMETRIC ACCURACY (PURE POLARISATION) (VAL) | | K |
| 19 | 012168 | RADIOMETRIC ACCURACY (CROSS POLARISATION) (VAL) | | K |
| 20 | 027010 | FOOTPRINT AXIS 1 (VAL) | | M |
| 21 | 028010 | FOOTPRINT AXIS 2 (VAL) | M | |
| 22 | 002099 | POLARISATION (VAL) | | CODE TABLE |
| 23 | 013048 | WATER FRACTION | | % |
| 24 | 025081 | INCIDENCE ANGLE (VAL) | | DEGREE |
| 25 | 025082 | AZIMUTH ANGLE (VAL) | DEGREE | |
| 26 | 025083 | FARADAY ROTATIONAL ANGLE (VAL) | | DEGREE |
| 27 | 025084 | GEOMETRIC ROTATIONAL ANGLE (VAL) | | DEGREE |
| 28 | 012080 | BRIGHTNESS TEMPERATURE REAL PART (VAL) | | K |
| 29 | 012081 | BRIGHTNESS TEMPERATURE IMAGINARY PART (VAL) | | K |
| 30 | 012082 | PIXEL RADIOMETRIC ACCURACY (VAL) | | K |
| 31 | 025174 | SMOS INFORMATION FLAG (VAL) | | FLAG TABLE |
| 32 | 033028 | SNAPSHOT OVERALL QUALITY | | CODE TABLE |

This provides the structure of the BUFR message. Within this structure, some of the provided codes might be updated by the WMO ET/DRC.

New Code Tables

- Concerning the Polarisation information (line 22) a new code table has been proposed and validated by WMO Code (002098 Polarisation). It is defined in agreement with the polarisation flag of the SMOS NRT product format specification of the Deimos document SO-ID-DMS-GS-0002 (v4.1), section 6.2.3. In the BUFR format its meaning is defined as:

| Code | Meaning |
|------|--|
| 0 | HH polarisation |
| 1 | VV polarisation |
| 2 | HV polarisation real valued component |
| 3 | HV polarisation imaginary valued component |
| 4-6 | Reserved |
| 7 | Missing value |

The two TB numbers (lines 28 and 29) are the 3rd and 4th Stokes parameter for the HV polarisation (code 2) and the 3rd and 4th Stokes parameter for the VH polarization (code 3). In case of pure polarization HH (code 0) and VV (code 1) only the line 28 is filled.

- Concerning the overall quality (line32) a new code table has been included to WMO code (overall quality). It is defined in agreement with the Product_Confidence of the SMOS NRT product format specification (document SO-TN-IDR-GS-0005):

| | |
|-----|--|
| 1 | Nominal |
| 2 | Degraded by SW error: any error reported by the algorithms |
| 3 | Degraded by instrument error |
| 4 | Degraded by corrupted/missing ADF |
| 5-6 | Reserved |
| 7 | Missing value |

The reserved value 5 indicates data degraded by calibration errors.

In case of multiple degradation causes, the following codes are used:

2 indicates any combination of multiple errors including SW error,

3 indicates any combination of multiple errors including instrument error and not including SW error,

6 indicates degraded by corrupted/missing ADF and degraded by calibration errors.

New Flag Table

For the SMOS information flag (line 31), a new flag table (code 025144) has been proposed to WMO Code. In agreement with the SMOS NRT product specification (SO-ID-DMS-GS-0002, v4.1, section 6.2.3) it is defined as:

| Bit number | Meaning |
|------------|---|
| 1 | Pixel is affected by RFI effects as identified in the AUX_RFILST or it has exceeded the BT thresholds |
| 2 | Pixel is located in the hexagonal alias directions centred on a Sun alias (if Sun is not removed, measurement may be degraded in these directions) |
| 3 | Pixel is close to the border delimiting the Extended Alias free zone or to the unit circle replicas borders. |
| 4 | Measurement is affected by the tails of a point source RFI as identified in the AUX RFI list (tail width is dependant on the RFI expected BT, from each snapshot measurements, corresponding to 0.16 of the radius of the RFI circle flagged) |
| 5 | Pixel is inside the exclusive zone of Alias free. |
| 6 | Pixel is located in a zone where a Moon alias was reconstructed |
| 7 | Pixel is located in a zone where Sun reflection has been detected |
| 8 | Pixel is located in a zone where a Sun alias was reconstructed |
| 9 | Measurement is affected by RFI effects in the corresponding polarisation as identified in the long trend analysis of telemetry data (NIR and System Temperatures) |
| 10 | Scene has not been combined with an adjacent scene in opposite polarisation during image reconstruction |
| 11 | Direct Moon correction has been performed during image reconstruction of this pixel |
| 12 | Reflected Sun correction has been performed during image reconstruction of this pixel |
| 13 | Direct Sun correction has been performed during image reconstruction of this pixel |
| All 14 | Missing value |

New Identifiers

- For the satellite identifier, the following new sub category has been added to the WMO Common Code Table C-13:

| Data category | International sub-category |
|-----------------------------|----------------------------|
| 12 Surface data (satellite) | 007 SMOS data |
- WMO Common Code Table C-5 will be updated with the SMOS satellite identifier (code figure proposed 046)
- WMO Common Code Table C-8 will be updated with the MIRAS instrument identifier (code figure proposed 176)

An example of expanded sequence

The sequence for SMOS data in a BUFR message is:

DATA DESCRIPTORS (UNEXPANDED)

1 312070

DATA DESCRIPTORS (EXPANDED)

| ELEMENT NAME | UNIT |
|---|-----------------|
| 1 001007 SATELLITE IDENTIFIER | CODE TABLE 1007 |
| 2 002019 SATELLITE INSTRUMENT TYPE | CODE TABLE 2019 |
| 3 001144 SNAPSHOT IDENTIFIER (VAL) | NUMERIC |
| 4 001124 GRID POINT IDENTIFIER (VAL) | NUMERIC |
| 5 030010 NUMBER OF GRID POINTS (VAL) | NUMERIC |
| 6 004001 YEAR | YEAR |
| 7 004002 MONTH | MONTH |
| 8 004003 DAY | DAY |
| 9 004004 HOUR | HOUR |
| 10 004005 MINUTE | MINUTE |
| 11 004006 SECOND | SECOND |
| 12 005001 LATITUDE (HIGH ACCURACY) | DEGREE |
| 13 006001 LONGITUDE (HIGH ACCURACY) | DEGREE |
| 14 007012 GRID POINT ALTITUDE (VAL) | M |
| 15 015012 TOTAL ELECTRON COUNT (VAL) | 1/M**2 |
| 16 012165 DIRECT SUN BRIGHTNESS TEMPERATURE (VAL) | K |
| 17 012166 SNAPSHOT ACCURACY (VAL) | K |
| 18 012167 RADIOMETRIC ACCURACY (PURE POLARISATION) (VAL) | K |
| 19 012168 RADIOMETRIC ACCURACY (CROSS POLARISATION) (VAL) | K |
| 20 027010 FOOTPRINT AXIS 1 (VAL) | M |
| 21 028010 FOOTPRINT AXIS 2 (VAL) | M |
| 22 002099 POLARISATION (VAL) | CODE TABLE |
| 23 013048 WATER FRACTION | % |
| 24 025081 INCIDENCE ANGLE (VAL) | DEGREE |
| 25 025082 AZIMUTH ANGLE (VAL) | DEGREE |
| 26 025083 FARADAY ROTATIONAL ANGLE (VAL) | DEGREE |
| 27 025084 GEOMETRIC ROTATIONAL ANGLE (VAL) | DEGREE |
| 28 012080 BRIGHTNESS TEMPERATURE REAL PART (VAL) | K |
| 29 012081 BRIGHTNESS TEMPERATURE IMAGINARY PART (VAL) | K |
| 30 012082 PIXEL RADIOMETRIC ACCURACY (VAL) | K |
| 31 025174 SMOS INFORMATION FLAG (VAL) | FLAG TABLE |
| 32 033028 SNAPSHOT OVERALL QUALITY | CODE TABLE |

Data size estimation

In average, one BUFR message will contain 4800 subsets which is equivalent to one snapshot with 4800 pixels. This averaged number can vary depending on the number of pixels considered in the snapshot. One file can contain one or more BUFR messages.

The data size of one subset (table) = 424 bits

Averaged number of subsets = 4800

Expected BUFR compression rate = 5
Total size of one snapshot = $(424/8)*4800/5 = 50880$ bytes
Number of snapshots per day = 72000

Total size per day = 3.66 GB

File naming convention

For each snapshot, acquired data are provided in a separate BUFR message. Each file might contain several BUFR messages. In the case the acquisition covers more than one orbit, we request a maximum of one orbit per file. The file naming convention for the SMOS NRT level1c brightness temperature product is defined as follow:

$\$Instrument_ \$SensingTime1_ \$SensingTime2_ \$Satellite_ \$orbit_ \$datatype_ \$GeneratingTime_ \$datalevel.bufr$

Where:

- $\$Instrument$ is the name of the instrument in 5 characters. It is fixed to 'miras'
- $\$SensingTime1 = \$YYYYMMDD_ \$HHMMSS$ is the first MIRAS integration time within the product
- $\$SensingTime2 = \$YYYYMMDD_ \$HHMMSS$ is the last MIRAS integration time within the product
- $\$YYYYMMDD$ is a 8 digits number to depict the year month day
- $\$HHMMSS$ is a 6 digits number for hour minute second
- $\$Satellite$ is the name of the satellite in 4 characters. It is fixed to: 'smos'
- $\$orbit$ is the 5 digits orbit number
- $\$datatype$: is 1 character, either 'o' for operational, or 't' for test in case of delayed or degraded data
- $\$GeneratingTime = \$YYYYMMDD_ \$HHMMSS$ is the time stamp of the BUFR generation date time
- $\$datalevel$: 3 characters fixed for level1c to '11c'

The character '_' is the separator character. The extension '.bufr' indicates that the file is a bufr file. For SMOS NRT Level 1c products, this naming convention leads to:
 $miras_ YYYYMMDD_ HHMMSS_ YYYYMMDD_ HHMMSS_ smos_ \$orbit_ o_ YYYYMMDD_ HHMMSS_ 11c.bufr$

BUFR encoding

BUFR messages can be encoded using the ECMWF BUFR software from ECMWF:
<http://www.ecmwf.int/products/data/software/bufr.html>

A description of BUFR format is provided in:
http://www.ecmwf.int/products/data/software/bufr_user_guide.pdf

For more information, WMO documents provide detailed description of BUFR format, including information on BUFR compression:
<http://www.wmo.ch/pages/prog/www/WDM/Guides/BUFRCREXGuide-English.html>

The BUFR files must be created using the WMO table version 14.
Compression setting must be:
ksec3(4)=192 if more than 1 subset
ksec3(4)=128 if 1 subset