UK Met Office, Exeter
WAFC London WAFS Upper Air Forecast GRIB2 Dataset Guide

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Change Record:

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1.0	23 March 2010	Original Issue	Chris Tyson, Met Office, WAFC London.
1.1	23 September 2010	Change to title, replacing 'Aviation' with 'Upper Air Forecasts', and similar changes in the body text. Addition of Change Record table.	Chris Tyson, Met Office, WAFC London.
1.2	13 December 2011	Update to Product Definition Template values following introduction of harmonised cb, icing and turbulence forecasts. Indication of new times of delivery for the harmonised cb, icing and turbulence forecasts. References to harmonised trial forecasts of cb, icing and turbulence added, with direction on how to obtain further information from WAFSOPSG webpages, see 2.1 g).	Chris Tyson, Met Office, WAFC London.
1.3	13 February 2013	Updated URLs 1.2, 9.1.1 and 9.1.2, Updated Table 3 Updated contact details, 10.1 Updated table references (throughout) References to provision of FL410 (175hPa) data included - Table AppA:1: T2 Parameter decode; Table AppA:2: ii Parameter decode; Table AppA:3: WAFC London WAFS Aviation GRIB2 Dataset. (note, FL410 data will be made available 14 November 2013 and accordance with Amendment 76 to ICAO Annex 3).	Chris Tyson, Met Office, WAFC London.
1.4	29 January 2015	Included information regarding relationship between WAFC London and WAFC Washington GRIB2 datasets (new section 2) Included information regarding the requirement that users decode flags/indicators explicitly, and do not 'assume' that particular values will be used (new section 2). Included information regarding known differences between WAFC London and WAFC Washington datasets (new appendix D)	Chris Tyson, Met Office, WAFC London.
1.5		Included references to additional flight level data for wind, temperature and relative humidity, to be effective with applicability of Amendment 77 to ICAO Annex 3 – *Meteorological Service to International Air Navigation*. See Appendix A.	Chris Tyson, Met Office, WAFC London.
1.6	30/03/2021	Updated to remove in-cloud turbulence fields, and to include the new 0.25 degree cumulonimbus, icing and turbulence fields which became effective with Amendment 79 to ICAO Annex 3.	Karen Shorey, Met Office WAFC London
1.6a	23/08/2021	Formatting errors in document repaired.	

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1. Introduction to WAFC London Upper Air Forecasts in GRIB2 format

1.1. The GRIB2 format was developed by the WMO. It is a binary format which contains gridded data. The name GRIB comes from **GR**idded **B**inary. GRIB2 was approved for experimental use by the WMO/CBS in 1998, and for operational use in 2000. It addressed the problem of the GRIB1 tables being full and no longer of capable of expansion/extension. GRIB2, introduced a more comprehensive parameter identification system, and expanding on the use of templates. The WMO are still accepting proposals to extend the specification. The Met Office submitted the proposal for "product definition template" 4.15 (Table AppB:3), which is used in some aviation fields and is discussed later in this document.

1.2. Historically, both WAFCs provided similar data (lower vertical, horizontal and temporal resolution) in GRIB Edition 1 format, and did so for many years. The GRIB1 version of the data was removed from the WAFS portfolio on 14th November 2013. The WAFCs now only provide gridded forecasts as required/defined by ICAO Annex 3 – *Meteorological Service for International Air Navigation* in GRIB2 format.

1.3. This document cannot possibly be a full treatment of GRIB2 as implemented for WAFS Upper Air Forecast GRIB2 products. It serves as a basic introduction of the main topics, and provides a brief overview of some aspects of implementation. The reader is directed to the more detailed guidance documents as necessary, most of which are available from freely accessible websites.

The latest GRIB2 specifications can be found on the following web page:

http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/VolumeI.2.html

The top link on that page (a blue cross) will take you to a document containing the full description of the GRIB2 and BUFR file formats. You will find the GRIB2 specification in the section entitled "PART B. BINARY CODES", subsection "b. List of binary codes", subsection "FM 92-XIV GRIB".

The GRIB2 templates and tables are also available separately from the following web page:

http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/LatestVERSION/LatestVERSION.html

2. Relationship between WAFC London and WAFC Washington data.

2.1. Whilst this document refers strictly to WAFC London data, both WAFC London and WAFC Washington put great efforts into the alignment of the datasets in order to minimise differences between them. Although some differences are known to exist, those differences are wholly within the international standards for WMO GRIB Edition 2. As such, it is imperative that all GRIB2 flags and indicators are explicitly checked and processed appropriately by decoding/visualising systems. Systems should not 'assume' that particular values will be set.

2.2. To assist users, a list of known differences between WAFC London and WAFC Washington WAFS GRIB2 datasets is provided in Appendix D.

3. Basic Explanation of GRIB2 structure

3.1. A GRIB2 message consists of eight sections:

0 Indicator Section - 'GRIB'

1 Identification Section

2 Local Use Section

3 Grid Definition Section

4 Product Definition Section

5 Data Representation Section

6 Bitmap Section

7 Data Section

8 End Section - '7777'

3.1.1 Section 0 – Indicator Section

This section identifies the file as a GRIB2 message, and specifies the edition number (GRIB1 or GRIB2). It also states the *"discipline"* of the message, which is the first element of the three-tier parameter identification used in GRIB2. Discipline can be meteorological, space, oceanographic, etc.

3.1.2 Section 1 – Identification Section

This tells us when the data was generated, which originating centre it came from and if it uses WMO or locally defined parameter tables (see 3.2, 'Parameter identification', below).

3.1.3 Section 2 – Local Use Section

This section can be used to store bespoke data of any kind. This is generally avoided and generating centres which have unsupported metadata are advised to submit proposals to the WMO to extend the specification instead.

3.1.4 Section 3 – Grid Definition Section

This describes the grid on which the data lies and uses the template system to allow the description of different types of grid, such as lat/lon, rotated lat/lon, polar stereographic etc. Currently, Met Office aviation products only use a regular, global lat/lon grid – see Grid Definition Template 3.0, Table AppB:1.

3.1.5 Section 4 – Product Definition Section

This identifies both the parameter and the *"product definition template"*.

The parameter is identified by *"parameter category"* and *"parameter number"* which, together with the discipline number from section 0, pinpoint an entry in a particular parameter table. For discipline 0 (meteorological), the *parameter category* can be temperature, moisture, cloud, etc. (see Code Table 4.2 in the GRIB2 specification).

The *product definition template* uses the template system to describe different products. It can, for example, be a forecast, ensemble forecast, probability forecast, forecast accumulation over time, radar product, etc. A list of the product definition templates used by aviation at The Met Office can be found here in Table AppB:3.

3.1.6 **Section 5 – Data Representation Section**

This uses the template system to specify what type of packing/compression is used to store the data. Template 5.0 specifies simple packing, where a reference value and scale factor(s) are used to pack the data. Template 5.40 (Table AppB:4) specifies simple packing with JPEG2000 compression. See also, Table AppB:6, JPEG2000 compression settings.

3.1.7 **Section 6 – Bitmap Section**

Currently, Met Office aviation messages do not use the bitmap section.

3.1.8 **Section 7 – Data Section**

This contains the data, formatted according to section 5 (data representation section). If section 5 specifies *data representation template 5.40*, then section 7 will use *data template 7.40*. See Table AppB:5.

3.1.9 **Section 8 – End Section**

A simple 4-byte ASCII string, “7777”, signifying the end of the message.

3.2. Parameter identification

3.2.1 As mentioned above, a parameter is identified in GRIB2 using three values, *discipline*, *category* and *number*. Currently, the Met Office uses parameters in the international tables defined by the WMO (see Code Table 4.2 in the GRIB2 specification). It is also possible to create a set of tables local to the Met Office. However, if a new, unsupported parameter is required in the future, we recommend submitting a proposal to the WMO for the new parameter to be added to their tables. This makes it easier to share our data

3.3. Data packing and JPEG2000 compression

JPEG2000 compression is set to lossless, in octet 22 of Table AppB:4.

The *simple data packing* method is now described.

Please also see *regulations 92.9.2* and *92.9.4* in the GRIB2 specification.

First, the decimal scaling (D) is applied.

Next, the minimum value in the field (*reference value, R)* is subtracted and stored.

Finally, the binary scaling (E) is applied. It can be employed to fit the maximum value into a prescribed number of bits. Currently, Met Office aviation products do not use binary scaling (E=0) because it can lead to different scaling factors being applied to different fields (as their maximum values can differ). As a side effect of this, fields with binary scaling may not be suitable for differencing analyses. See also section 7.

3.4. Product definition template 4.15 – spatially processed data

Some Met Office aviation products are spatial means or maximums. The only existing GRIB2 template for specifying means or maximums is *product definition template 4.8*. Unfortunately, this template only describes temporally processed products, so The Met Office have proposed the new product definition template 4.15, for spatially processed products – see Table AppB:3.

3.5. Generating process identifiers

Most product definition templates (except radar and satellite) include the two metadata items, *"Background generating process identifier"* and *"Analysis or Forecast Generating Process Identifier",* which are defined by the originating centre. The Met Office definitions for these are as follows:

Value	Process
00	Reserved
01	Supercomputer Deterministic Atmospheric Models
02	
03	
04	Supercomputer Ensemble Atmospheric Models
05	
06	Supercomputer Climate Models
07	
08	Supercomputer Deterministic Wet Models
09	Supercomputer Ensemble Wet Models
10	Swift
11	UKPP
12	Autosat
13	FORMOST
14	NAME Dispersion Model
15	Not assigned
16	Not assigned
17	Not assigned
18	Not assigned
19	Not assigned
20	Not assigned
21	Not assigned
22	Not assigned
23	Not assigned…
..	…
254	…
255	Reserved

Table 1: GRIB2 – Product Definition Template, Octet 13 Background Generating Process Identifiers from Originating Centre 74 (UK Met Office, Exeter, England)

Value	Process
00	Reserved
01	Global Model
02	North Atlantic and European Model
03	UK 4 km
04	UK 1.5km on demand
05	Regional Model – Area of coverage not publicised
06	Regional Model – Area of coverage not publicised
07	Africa Model
08	Regional 4 km Model – Area of coverage not publicised
09	Not assigned
10	Not assigned
11	Not assigned
12	Not assigned
13	Not assigned
14	Not assigned
..	…
254	…
255	Reserved

Table 2: GRIB2 – Product Definition Template Octet 14 (where Octet 13 = 1) Analysis or Forecast Generating Process Identifiers from Originating Centre 74 (UK Met Office, Exeter, England) GRIB2 – Product Definition Template Octet 14, Sub-table for Supercomputer Deterministic Atmospheric Models (Octet 13 = 1)

Product Discipline Section 0 Octet 7	Production Status of Data Section1 Octet 20	Product Category Section 4 Octet 10	Parameter Number Section 4 Octet 11	Product Definition Template Section 4 Octet 8-9	Statistical Processing Flag Section 4 Octet 35	Level Indicator Section 4 Octet 23	Decimal Scaling factor Section 5 Octets 18-19	Field Parameter	Unit
0	0	0	0	0	-	100	1	Temperature on standard pressure levels	K
0	0	0	0	0	-	7	1	Tropopause Temperature	K
0	0	1	1	0	-	100	1	Relative Humidity on standard pressure levels	%
0	0	2	2	0	2	6	1	Maximum wind u-component	m/s
0	0	2	2	0	-	100	1	Wind u-component on standard pressure levels	m/s
0	0	2	3	0	-	100	1	Wind v-component on standard pressure levels	m/s
0	0	2	3	0	2	6	1	Maximum wind v-component	m/s
0	0	3	3	0	-	7	0	Tropopause Height(ICAO)	m
0	0	3	3	0	2	6	0	Maximum Wind Height(ICAO)	m
0	1	3	3	0	-	11	0	ICAO Height at CB Base	m
0	1	3	3	0	-	12	0	ICAO Height at CB Top	m
0	0	3	5	0	-	100	0	Geopotential height of standard levels	gpm
0	1	6	25	0	-	10	1	Horizontal extent of Cumulonimbus*	%
0	1	19	20	15	0	100	2	Mean Icing at standard pressure levels*	%
0	1	19	20	15	2	100	2	Maximum Icing at standard pressure levels*	%
0	1	19	22	15	0	100	1	Mean CAT at standard pressure levels*	%
0	1	19	22	15	2	100	1	Maximum CAT at standard pressure levels*	%
0	1	19	30	0	-	100		Eddy Dissipation Parameter	$m^{2/3}\ s^{-1}$
0	1	19	37	0	-	100		Icing Severity	-

Table 3: Met Office WAFS Parameters - specifications in the GRIB-2 headers. The parameters marked with an asterisk (*) are trial and evaluation forecasts.

4. Availability of GRIB2 products

4.1. All standard GRIB2 products are available for immediate transmission once generated. The schedule of availability is given in

4.2. . At the moment, harmonised versions of forecasts for cumulonimbus cloud (CB), icing and turbulence are delivered later due to the extra processing required.

5. GRIB2 bulletins available from the Met Office

5.1. Details of the Met Office's Numerical Weather Prediction (NWP) GRIB2 products, available from Exeter (EGRR), appear in the tables in Appendix A.

6. Ownership of WAFS Aviation GRIB2 data

6.1. WAFS Aviation GRIB2 data is produced for and under authority of the International Civilian Aviation Organisation (ICAO). WAFC London Aviation GRIB2 data is regulated, on behalf of ICAO, by the United Kingdom Civil Aviation Authority. Applications for access to and use of WAFC London GRIB2 data, should – in the first instance – be made to:

Karen Shorey
SADIS Manager
Met Office
FitzRoy Road
Exeter
EX1 3PB
United Kingdom
E-mail: SADISmanager@metoffice.gov.uk

7. Compression of Data

7.1. The WAFS Aviation GRIB2 bulletins are compressed using JPEG2000. This is a WMO approved compression algorithm. WAFC London compresses its Aviation GRIB2 using a commercial software application from Luratech, meeting necessary standards for the provision of services to the aviation industry.

7.2. For decompression of GRIB2 files, users and workstation vendors should implement decompression utilities compliant with the JPEG2000 standard, of which there are a number available - both commercially and open source - or develop in-house utilities compliant with the standard. WAFC London cannot recommend one utility over another, nor can it expressly certify or otherwise the fitness of purpose of individual decompression utilities. Users/workstation vendors should satisfy themselves that the software employed in their systems meets appropriate QMS standards. Table AppB:6 (copied below) defines the characteristics of the compression choices used during the creation of the data.

Property	Setting
File Format	JPEG2000 codestream
Compression Quality	Lossless compression
Colourspace	Greyscale images
Wavelet filter	Reversible filter
Wavelet Levels	5 wavelet levels

Table 4: Characteristics of JPEG Compression used for GRIB-2 Products at the UK Met Office

8. Format of Bulletins

8.1. The WAFC London WAFS Aviation GRIB2 dataset is issued by the Met Office as Meteorological Bulletins and encapsulated in a telecommunications envelope. The content of this envelope depends on the communications protocol used. After the end section, an ASCII string: 'carriage return, carriage return, line feed, end of transmission' (0D0D0A03) hex. is added. Full details of the format of a meteorological bulletin, also the structure that is added as part of the telecommunications transmission, can be found in Manual on the Global Telecommunication System (WMO No. 386), Volume I: Global Aspects, Part II: Operational Procedures for the Global Telecommunication System.

9. Reference

9.1. The latest GRIB2 specifications can be found on the following web page: http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/VolumeI.2.html

9.2. The top link (a blue cross) will take you to a document containing the full description of theGRIB2 and BUFR file formats. You will find the GRIB2 specification in the section entitled "PART B. BINARY CODES", subsection "b. List of binary codes", subsection "FM 92-XIV GRIB".

9.3. The GRIB2 templates and tables are also available separately from the following web page: http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/LatestVERSION/LatestVERSION.html (This link does not include the regulations, nor a description of the grib sections)

10. Requests for further information and access to the products

10.1. Requests for further technical information on the content of this document, or initial requests for provision of WAFS Aviation GRIB2 products should be addressed to the SADIS manager (SADISmanager@metoffice.gov.uk).

Appendix A: WAFS Aviation GRIB2 Bulletin Availability and Definitions

GRIB2 code (FM 92 GRIB Edition 2)

Parameter	Description	Table
T_1	Parameter decode table	Table AppA:2
T_2	Parameter decode table	Table AppA:3
A_1	Grid-area and grid-length decode table	Table AppA:4
A_2	Analysis and forecast-time decode table	Table AppA:5
ii	Level designator decode	Table AppA:6

Table AppA:1: GRIB2 code (FM 92 GRIB Edition 2)

Note:
This guide lists the WAFC London, WAFS Aviation GRIB2 dataset distributed by the Met Office.

T_1 Parameter decode

T_1 Code	Description
Y	This will always be the case for WAFS Aviation GRIB2 data referenced in this manual

Table AppA:2: T_1 Parameter decode

T_2 Parameter decode

T_2 Code	Description	Units	Bulletin headers
B	CB horizontal extent	%	YBX[C-M]01 EGRR
B	CB horizontal extent	%	YBY[C-M]01 EGRR
H	Geopotential Height of Standard levels	m	YHX[C- M][85,*75*,70,60,50,*45*,40,35,30,27,25,23,20,18, 15,***13***,10] EGRR
H	Maximum Wind Height (ICAO)	m	YHX[C-M]96 EGRR
H	Tropopause Height (ICAO)	m	YHX[C-M]97 EGRR
H	Height at CB Base (ICAO)	m	YHX[C-M]02 EGRR
H	Height at CB Base (ICAO)	m	YHY[C-M]02 EGRR
H	Height at CB Top (ICAO)	m	YHX[C-M]03 EGRR
H	Height at CB Top (ICAO)	m	YHY[C-M]03 EGRR
I	Mean icing potential	%	YIX[C-M][80,70,60,50,40,30] EGRR
I	Maximum icing potential	%	YIX[C-M][81,71,61,51,41,31] EGRR
I	Icing Severity	Category	YIY [C-M][80,70,60,50,40,30] EGRR
L	Mean CAT potential	% 100 km^{-1}	YLX[C-M][40,35,30,25,20,15] EGRR
L	Maximum CAT potential	% 100 km^{-1}	YLX[C-M][41,36,31,26,21,16] EGRR
L	Turbulence Severity	$m^{2/3}$ s^{-1}	YLY [C-M][70,60,50,40,35,30,25,20,15] EGRR
R	Relative humidity	%	YRX[C-M][85,*75*,70,60,50] EGRR
T	Temperature	K	YTX[C-M][85,70,60,50,40,35,30,27,25,23,20,18,15,10] EGRR
T	Tropopause Temperature	K	YTX[C-M]97 EGRR
U	Eastward wind component	ms^{-1}	YUX[C- M] [85,*75*,70,60,50,*45*,40,35,30,27,25,23,20, 18,15,*13*,10] EGRR
U	Maximum Eastward wind component	ms^{-1}	YUX[C-M]96 EGRR
V	Northward wind component	ms^{-1}	YVX[C-M][85,*75*,70,60,50,*45*,40,35,30,27,25,23,20, 18,15,*13*,10] EGRR
V	Maximum Northward wind component	ms^{-1}	YVX[C-M]96 EGRR

Table AppA:3: T_2 Parameter decode

Notes: CB – Cumulonimbus
^ Tropopause Height in WAFS Aviation GRIB2 data is capped at FL600.

A_1 and A_2 Grid-area and grid-length decode

A_1 Parameter decode

A_1 Code	Description
X	This denotes 1.25 degree horizontal resolution WAFS Aviation GRIB2 data referenced in this manual and represents coverage of the entire globe in one bulletin
Y	This denotes 0.25 degree horizontal resolution WAFS Aviation GRIB2 data referenced in this manual and represents coverage of the entire globe in one bulletin

Table AppA:4: A_1 Parameter decode

A_2 Analysis and forecast-time decode

Global atmospheric model WAFS Aviation GRIB2 for civil aviation (1.25º x 1.25º resolution) Y*X[C-M] EGRR**

A_2 Code	Decode	A_2 Code	Decode	A_2 Code	Decode
C	T + 6	G	T + 18	K	T + 30
D	T + 9	H	T + 21	L	T + 33
E	T + 12	I	T + 24	M	T + 36
F	T + 15	J	T + 27	-	-

Table AppA:5: A_2 Parameter decode

ii Level designator decode

ii Code	Decode	ii Code	Decode	ii Code	Decode
97	Level of the tropopause	50	500 hPa	23*	225 hPa
96	Level of maximum wind	*45*	*450 hPa*	21*	200 hPa
85	850 hPa	41*	400 hPa	20	200 hPa
81*	800 hPa	40	400 hPa	18	175 hPa
80	800 hPa	36*	350 hPa	16*	150 hPa
75	*750 hPa*	35	350 hPa	15	150 hPa
71*	700 hPa	31*	300 hPa	*13*	*125 hPa*
70	700 hPa	30	300 hPa	10	100 hPa
61*	600 hPa	27*	275 hPa	03	n/a
60	600 hPa	26*	250 hPa	02	n/a
51*	500 hPa	25	250 hPa	01	n/a

Table AppA:6: ii Parameter decode

Note:

* These levels do not follow the standard WMO guidance given in following publication - WMO No. 386 Manual on the Global Telecommunication System, Part II - Operational Procedures for the GTS, ATTACHMENT II–5 - DATA DESIGNATORS T1T2A1A2ii IN ABBREVIATED HEADINGS in TABLE D2

Time of availability of WAFC London GRIB2 Bulletins

	1.25 degree data **YRX, YBC, YTX, YUX, YVX**	**1.25 degree Hazard data** **YHX, YIX,**	**0.25 degree Hazard data** **YIY, YLY, YBY, YHY**
ICAO delivery target	5-hours	5-hours	5-hours
Time data is usually available on Met switch[1]	03:30 hours	04:20 hours	04:30 hours
Data time 0000 UTC	Available at 03:30 UTC	Available at 04:20 UTC	Available at 04:30 UTC
Data time 0600 UTC	Available at 09:30 UTC	Available at 10:20 UTC	Available at 10:30 UTC
Data time 1200 UTC	Available at 15:30 UTC	Available at 16:20 UTC	Available at 16:30 UTC
Data time 1800 UTC	Available at 21:30 UTC	Available at 22:20 UTC	Available at 22:30 UTC

Table AppA:7: *Time of availability of WAFC London GRIB2 Bulletins*

Note: Schedule of delivery of GRIB2 data beyond MetSwitch to external users will depend upon the medium used to receive the data.

[1] *MetSwitch is the Met Office Message Switch. Subsequent delivery to customer will depend on connection type and bandwidth. Targets to be agreed separately bearing in mind the stated availability on MetSwitch*

Appendix B: GRIB2 templates used in WAFC London aviation products

GRIB2 Grid Definition Template 3.0:

Octet No.	***Contents***
15	*Shape of the Earth (see Code table 3.2)*
16	*Scale factor of radius of spherical Earth*
17–20	*Scaled value of radius of spherical Earth*
21	*Scale factor of major axis of oblate spheroid Earth*
22–25	*Scaled value of major axis of oblate spheroid Earth*
26	*Scale factor of minor axis of oblate spheroid Earth*
27–30	*Scaled value of minor axis of oblate spheroid Earth*
31–34	*Ni – number of points along a parallel*
35–38	*Nj – number of points along a meridian*
39–42	*Basic angle of the initial production domain (see Note 1)*
43–46	*Subdivisions of basic angle used to define extreme longitudes and latitudes, and direction increments (see Note 1)*
47–50	*La1 – latitude of first grid point (see Note 1)*
51–54	*Lo1 – longitude of first grid point (see Note 1)*
55	*Resolution and component flags (see Flag table 3.3)*
56–59	*La2 – latitude of last grid point (see Note 1)*
60–63	*Lo2 – longitude of last grid point (see Note 1)*
64–67	*Di – i direction increment (see Note 1)*
68–71	*Dj – j direction increment (see Note 1)*
72	*Scanning mode (flags – see Flag table 3.4)*
73–nn	*List of number of points along each meridian or parallel. (These octets are only present for* *quasi-regular grids as described in Notes 2 and 3)*

Table AppB:1: Grid Definition Template 3.0 – latitude/longitude (or equidistant cylindrical, or Plate Carrée)

Notes:

(1) Basic angle of the initial production domain and subdivisions of this basic angle are provided to manage cases where the recommended unit of 10–6 degrees is not applicable to describe the extreme longitudes and latitudes, and direction increments. For these last six descriptors, the unit is equal to the ratio of the basic angle and the subdivisions number.

For ordinary cases, zero and missing values should be coded, equivalent to respective values of 1 and 106 (10–6 degrees unit).

(2) For data on a quasi-regular grid, where all the rows or columns do not necessarily have the same number of grid points, either Ni (octets 31–34) or Nj (octets 35–38) and the corresponding Di (octets 64–67) or Dj (octets 68–71) shall be coded with all bits set to 1 (missing). The actual number of points along each parallel or meridian shall be coded in the octets immediately following the grid definition template (octets [xx+1]–nn), as described in the description of the grid definition section.

(3) A quasi-regular grid is only defined for appropriate grid scanning modes. Either rows or columns, but not both simultaneously, may have variable numbers of points or variable spacing. The first point in each row (column) shall be positioned at the meridian (parallel) indicated by octets 47–54. The grid points shall be evenly spaced in latitude (longitude).

(4) A scaled value of radius of spherical Earth, or major or minor axis of oblate spheroid Earth is derived from applying the appropriate scale factor to the value expressed in metres.

Product Definition Template 4.0:

Octet No.	***Contents***
10	*Parameter category (see Code table 4.1)*
11	*Parameter number (see Code table 4.2)*
12	*Type of generating process (see Code table 4.3)*
13)	*Background generating process identifier (defined by originating centre*
14	*Analysis or forecast generating process identifier (defined by originating centre)*
15–16	*Hours of observational data cutoff after reference time (see Note)*
17	*Minutes of observational data cutoff after reference time*
18	*Indicator of unit of time range (see Code table 4.4)*
19–22	*Forecast time in units defined by octet 18*
23	*Type of first fixed surface (see Code table 4.5)*
24	*Scale factor of first fixed surface*
25–28	*Scaled value of first fixed surface*
29	*Type of second fixed surface (see Code table 4.5)*
30	*Scale factor of second fixed surface*
31–34	*Scaled value of second fixed surface*

Table AppB:2: Product Definition Template 4.0 analysis or forecast at a horizontal level or in a horizontal layer at a point in time

Note

1) Hours greater than 65534 will be coded as 65534.

Product Definition Template 4.15:

Octet No.	***Contents***
10	*Parameter category (see Code Table 4.1)*
11	*Parameter number (see Code Table 4.2)*
12	*Type of generating process (see Code Table 4.3)*
13	*Background generating process identifier (defined by originating centre)*
14	*Analysis or forecast generating process identified (see Code ON388 Table A)*
15-16	*Hours after reference time data cutoff (see Note 1)*
17	*Minutes after reference time data cutoff*
18	*Indicator of unit of time range (see Code Table 4.4)*
19-22	*Forecast time in units defined by octet 18 (see Note 2)*
23	*Type of first fixed surface (see Code Table 4.5)*
24	*Scale factor of first fixed surface*
25-28	*Scaled value of first fixed surface*
29	*Type of second fixed surfaced (see Code Table 4.5)*
30	*Scale factor of second fixed surface*
31-34	*Scaled value of second fixed surfaces*
35	*Statistical process used within the spatial area defined by octet 36 (see Code Table 4.10)*
36	*Type of spatial processing used to arrive at given data value from source data (see Code Table 4.15)*
37	*Number of data points used in spatial processing defined in octet 36*

Table AppB:3: Product Definition Template 4.15

Notes:

(1) Hours greater than 65534 will be coded as 65534.
(2) The reference time in section 1 and the forecast time together define the beginning of the overall time interval.

Data Representation Template 5.40

Octet No.	*Contents*
12–15	*Reference value (R) (IEEE 32-bit floating-point value)*
16–17	*Binary scale factor (E)*
18–19	*Decimal scale factor (D)*
20	*Number of bits required to hold the resulting scaled and referenced data values (i.e. depth of the grayscale image) (see Note 2)*
21	*Type of original field values (see Code table 5.1)*
22	*Type of compression used. (see Code table 5.40)*
23	*Target compression ratio, M:1 (with respect to the bit-depth specified in octet 20), when octet 22 indicates lossy compression. Otherwise, set to missing (see Note 3)*

Table AppB:4: Data Representation Template 5.40 – Grid point data – JPEG 2000 code stream format

Notes:

(1) The intent of this template is to scale the grid point data to obtain desired precision, if appropriate, and then subtract out reference value from the scaled field as is done using Data Representation Template 5.0. After this, the resulting grid point field can be treated as a grayscale image and is then encoded into the JPEG 2000 code stream format. To unpack the data field, the JPEG 2000 code stream is decoded back into an image, and the original field is obtained from the image data as described in regulation 92.9.4, Note (4).

(2) The JPEG 2000 standard specifies that the bit-depth must be in the range of 1 to 38 bits.

(3) The compression ratio M:1 (e.g. 20:1) specifies that the encoded stream should be less than ((1/M) x depth x number of data points) bits, where depth is specified in octet 20 and number of data points is specified in octets 6-9 of the Data Representation Section.

(4) The order of the data points should remain as specified in the scanning mode flags (Flag Table 3.4) set in the appropriate Grid Definition Template, even though the JPEG 2000 standard specifies that an image is stored starting at the top left corner. Assuming that the encoding software is expecting the image data in raster order (left to right across rows for each row), users should set the image width to Ni (or Nx) and the height to Nj (or Ny) if bit 3 of the scanning mode flag equals 0 (adjacent points in i (x) order), when encoding the "image". If bit 3 of the scanning mode flags equals 1 (adjacent points in j (y) order), it may be advantageous to set the image width to Nj (or Ny) and the height to Ni (or Nx).

(5) This template should not be used when the data points are not available on a rectangular grid, such as occurs if some data points are bit-mapped out or if section 3 describes a quasi-regular grid. If it is necessary to use this template on such a grid, the data field can be treated as a one dimensional image where the height is set to 1 and the width is set to the total number of data points specified in octets 6-9..

(6) Negative values of E or D shall be represented according to Regulation 92.1.5.

Data Template 7.40

Data template 7.40 – Grid point data – JPEG 2000 code stream format

Octet No.	***Contents***
6–nn	*JPEG 2000 code stream as described in Part 1 of the JPEG 2000 standard.* *(ISO/IEC 15444–1:2000)*

Table AppB:5: Data Template 7.40 – Grid point data – JPEG 2000 code stream format

Notes

1) For most templates, details of the packing process are described in regulation 92.9.4

2) For simplicity, image data should be packed specifying a single component (i.e. grayscale image) instead of a multicomponent color image.

JPEG2000 Compression Settings

Property	**Setting**
File Format	JPEG2000 codestream
Compression Quality	Lossless compression
Colourspace	Greyscale images
Wavelet filter	Reversible filter
Wavelet Levels	5 wavelet levels

Table AppB:6: Compression Settings used by WAFC London for WAFS Aviation GRIB2

Appendix C: List of abbreviations used in this guide

ASCII	American Standard Code for Information Interchange
BUFR	Binary Universal Form for the Representation of Meteorological Data
CAT	Clear Air Turbulence
CB	Cumulonimbus
GRIB	Gridded Binary code
GRIB2	Gridded Binary code – Edition 2
GTS	Global Telecommunication System
ICAO	International Civil Aviation Organization
IEC	International Electrotechnical Commission
ISO	International Organisation for Standardisation
JPEG	Joint Photographic Experts Group
JPEG2000	A standard defined and owned by JPEG
NWP	Numerical Weather Prediction
WAFC	World Area Forecast Centre
WAFS	World Area Forecast System
WAFSOPSG	World Area Forecast System Operations Group
WMO	World Meteorological Organization

Appendix D: Known differences between WAFC London and WAFC Washington WAFS GRIB2 datasets.

Below are the known differences between WAFC London and WAFC Washington WAFS GRIB2 datasets. Whilst WAFC London and WAFC Washington may have differences with regard to the aspects noted below, the practices are within the standards of the WMO GRIB Edition 2 protocols. All systems decoding/visualising WAFS GRIB2 data should explicitly check all flags and indicators, and process accordingly.

1) Scanning mode.

WAFC London scanning mode is from South Pole to North Pole.
WAFC Washington scanning mode is from North Pole to South Pole.

Users should apply the appropriate processes for decoding the scanning mode as per the setting in GRIB-2 header, Section 3 Octet 72