Proposal for a new RO BUFR template

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We need your help now

- You should have an email with the proposed changes to BUFR Section 4 (the data section)
  - Sent to IROWG mailing list
  - Sent out by Leslie to all participants
- Still some remaining questions
- We need your feedback by **Friday 18th October**
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  - Need to prepare changes well in advance

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Main changes

- Add capability for PRO and ARO
- Additional diagnostic fields
  - Easy addition of future diagnostics in new code table
- New flag table (yet to be finalized)
- Explicit descriptors for estimated errors of measurements

Changes compared to current BUFR are marked in blue in following slides

WIGOS station identifier

Data Field	Element Name	Descrip.	Table B Scale	Table B Ref. Val.	Table B Width	Units	Comments
Radio Occultation header							
1–4	**WIGOS station identifier**	**3 01 150**					
1	*Identifier series*	*0 01 125*	0	0	4	Numeric	
2	*Issuer of identifier*	*0 01 126*	0	0	16	Numeric	
3	*Issue number*	*0 01 127*	0	0	16	Numeric	
4	*Local identifier*	*0 01 128*	0	0	128	Character	

Requirement for all new BUFR formats

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Introducers for satellite or aircraft data

5	**Short delayed replication factor**	**0 31 000**	0	0	1	Numeric	Indicate presence of satellite RO header (*n0* = 0 or 1)
6–8	**Satellite data introducer**	**New**					
6	*Satellite Identifier*	*0 01 007*	0	0	10	Code Table	LEO or LEO constellation – **See Table 1**
7	*Satellite sub-identifier*	*0 01 016*	0	0	16	Numeric	Satellite ID in LEO constellation (missing if not applicable)
8	*Satellite instrument*	*0 02 019*	0	0	11	Code Table	e.g. 202 = GRAS – **See Table 2**
N0	*(end delayed replication – presence of satellite RO header)*						*N0 = 5+3.n0 elements*
	Delayed replication	**1 01 000**					Delayed replication of next descriptor
9	**Short delayed replication factor**	**0 31 000**	0	0	1	Numeric	Indicate presence of aircraft or station RO header
10–11	**Aircraft or station data introducer**	**New**					
10	*Station or site name*	*0 01 018*	0	0	40	Character	
11	*Upper air instrument*	*0 02 006*	0	0	6	Code Table	
	(end delayed replication – presence of aircraft or station RO header)						

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Specify where reference time is located

Local Earth parameters							
41	**SLTA (at reference time)**	**New**	0	-400000	19	Metres	-400 – 124km to 1m
42–43	**Location (high accuracy)**	**3 01 021**					
42	*Latitude*	*0 05 001*	5	-9000000	25	Degrees	to 10^{-5} deg (~1m) wrt WGS-84
43	*Longitude*	*0 06 001*	5	-18000000	26	Degrees	to 10^{-5} deg (~1m) wrt WGS-84
44–46	**Location of point**	**3 04 030**					(X, Y, Z) centre of curvature to 1cm

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Specify start and end of occultation

Time period of occultation							
50	**Time period** (between reference time and start of occultation)	**0 04 026**	0	-4096	13	Second	-4096 – 4096s (normally negative)
51	**Time period** (between reference time and end of occultation	**0 04 026**	0	-4096	13	Second	-4096 – 4096s (normally positive)

Indicates a timespan for following data

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New diagnostics for whole profile

Diagnostic quality information							
52	**Signal-to-noise ratio**	**New**	3	0	20	Numeric	Above atmosphere
53	**Bending angle variance 60–80km**	**New**	8	0	16	Radians	Relative to climatology
54	**Dry pressure at 15km**	**New**	-1	0	14	Pa	0.1 – 1100 hPa to 0.1 hPa
55	**Height of top of ducting**	**New**	0	0	13	Metres	Geometric altitude, 0 – 8km to 1m, wrt local surface

Data Field	Element Name	Descrip.	Table B Scale	Table B Ref. Val.	Table B Width	Units	Comments
56	**Planetary boundary layer height**	**New**	0	0	13	Metres	Geometric altitude, 0 – 8km to 1m, wrt local surface
57	**Tropopause height**	**New**	0	0	15	Metres	Geometric altitude, 0 – 32km to 1m, wrt Geoid (MSL)
58	**L2-extrapolation height**	**New**	0	0	15	Metres	Impact height, 0 – 32km to 1m
59	**GO/WO transition height**	**New**	0	0	15	Metres	Impact height, 0 – 32km to 1m
60	**CL/OL transition height**	**New**	0	0	15	Metres	Impact height, 0 – 32km to 1m

Are more needed?

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Step 1b (bending angle) data

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Add time information to occultation

RO 'Step 1b' data *(see Notes 2 & 5)*								
	Delayed replication	**1 23 000**						Delayed replication of next 23 descriptors
61	**Replication factor**	**0 31 002**		0	0		16	Numeric	Number of Step 1b samples
62–63	**Location (high accuracy)**	**3 01 021**						
62	*Latitude*	*0 05 001*		5	-9000000		25	Degrees	to 10^{-5} deg (~1m) wrt WGS-84
63	*Longitude*	*0 06 001*		5	-18000000		26	Degrees	to 10^{-5} deg (~1m) wrt WGS-84
	Increase Table B scale, reference value and bit width (all at once)	**2 07 003**							Add 3 to scale, multiply reference value by 1000 and add 10 to bit width
64	**Time displacement**	**0 04 026**	(3)	0	(-4096000) -4096	(23)	13	Second	-4000 – 4000s to 1ms
	Change scale, reference value and bit width to Table B	**2 07 000**							
65	**Bearing or azimuth**	**0 05 021**		2	0		16	Deg. True	GNSS-to-LEO line of sight
	Delayed Replication	**1 12 000**							Delayed replication of next 12 descriptors
66	**Replication factor**	**0 31 001**		0	0		8	Numeric	Number of frequencies

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PRO & accuracy changes

	Change Table B scale	**2 02 134**					Add 6 to scale
67	**Satellite channel centre frequency**	**0 02 153**	(-2) -8	0	26	Hz	0 – 6.7GHz, to 0.1kHz, Ionosphere corrected = 0
68	**Signal type**	**New**	0	0	24	Character	Three-letter code, RINEX convention
	Change scale to Table B	**2 02 000**					
69	**Impact Parameter**	**0 07 040**	1	62 000 000	22	Metres	6200–6600 km to 10cm (distance from centre of curvature)
70	**Bending Angle**	**0 15 037**	8	-100 000	23	Radians	-10^{-3} – 8×10^{-2} rad to 10^{-8} rad
71	**Estimated error in bending angle**	**New**	8	0	20	Radians	0 – 10^{-2} rad to 10^{-8} rad
72	**Calibrated phase difference**	**New**	3	-500	10	Metres	-50 – 50cm to 1mm
73	**Estimated error in calibrated phase difference**	**New**	3	0	7	Metres	0 – 12cm to 1mm

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ARO (or station RO) section

74	**Short delayed replication factor**	**0 31 000**		0	0		1	Numeric	Indicate presence of aircraft or station RO data
75-78	**Aircraft or station RO data**	**New**							
	Increase Table B scale, reference value and bit width (all at once)	*2 07 001*							Add 1 to scale, multiply reference value by 10, and add 4 to bit width
75	*Height (of RO antenna)*	*0 10 007*	(1)	0	(-10 000) -1000	(21)	17	Metres	Geometric altitude, -1km to 100km, wrt Geoid (MSL)
	Change scale, reference value and bit width to Table B	*2 07 000*							
76	*Atmospheric refractivity (in-situ at RO antenna)*	*0 15 036*		3	0		19	N-units	0 – 500 to 10^{-3} N-units
77	*Bending angle (partial)*	*0 15 037*		8	-100 000		23	Radians	-10^{-3} – $8x10^{-2}$ rad to 10^{-8} rad
78	*Estimated error in bending angle (partial)*	*New*		8	0		20	Radians	0 – 10^{-2} rad to 10^{-8} rad
	(end delayed replication – presence of aircraft or station RO data)								

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Flexible diagnostics

80	**Replication factor**	**0 31 001**	0	0	8	Numeric	Number of diagnostic entries

Data Field	Element Name	Descrip.	Table B Scale	Table B Ref. Val.	Table B Width	Units	Comments
81	**Radio occultation Diagnostic type**	**New**	0	0	5	Code Table	**See Table 6**
82	**Decimal scale of following significands**	**0 08 090**	0	-127	8	Numeric	Decimal scale (see next descriptor)
83	**Scaled diagnostic**	**New**	0	-131 071	18	Numeric	Scaled value (actual value = scaled value x $10^{\text{decimal scale}}$)
84	**Decimal scale of following significands** *(end delayed replication – number of diagnostic entries)*	**0 08 090**	0	-127	8	Numeric	Missing = off

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Step 2a (refractivity) data

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Add geopotential height and dry temperature

	Increase Table B scale, reference value and bit width (all at once)	**2 07 001**						Add 1 to scale, multiply reference value by 10, and add 4 to bit width
87	**Height**	**0 07 007**	(1)	0	(-10 000) -1 000	(21)	17	metres	Geometric altitude, -1km to 100km to 10cm, wrt Geoid (MSL)
88	**Geopotential height** *(see Note 11)*	**0 10 009**	(1)	0	(-10 000) -1 000	(21)	17	gpm	Geopot. altitude, -1km to 100km to 10cm, wrt Geoid (MSL)
89	**Atmospheric refractivity**	**0 15 036**	(4)	3	0	(23)	19	N-units	0 – 500, to 10^{-4} N-units
90	**Estimated error in atmospheric refractivity**	**New**	(4)	3	0	(20)	16	N-units	0 – 65, to 10^{-4} N-units
91	**Dry temperature**	**New**	(2)	1	0	(16)	12	K	150 – 350K, to 0.01 K
	Change scale, reference value and bit width to Table B	**2 07 000**							

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Flexible diagnostics

93	**Replication factor**	**0 31 001**	0	0	8	Numeric	Number of diagnostic entries
94	**Radio occultation Diagnostic type**	**New**	0	0	5	Code Table	**See Table 6**
95	**Decimal scale of following significands**	**0 08 090**	0	-127	8	Numeric	Decimal scale (see next descriptor)
96	**Scaled diagnostic**	**New**	1	-131 071	18	Numeric	Scaled value (actual value = scaled value x $10^{\text{decimal scale}}$)
97	**Decimal scale of following significands** (*end delayed replication – number of diagnostics entries*)	**0 08 090**	0	-127	8	Numeric	Missing = off

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Level 2b (1D-Var) data

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Accuracy changes

RO 'Level2b' data *(see Notes 3–5 & 12)*							
	Delayed replication	**1 08 000**					Delayed replication of next 8 descriptors
98	**Replication factor**	**0 31 002**	0	0	16	Numeric	Number of Step 2b samples
99	**Geopotential height** *(see Note 12)*	**0 07 009**	0	-1 000	17	gpm	Geopot. altitude, -1km to 100km, wrt Geoid (MSL)
100	**Pressure**	**0 10 004**	-1	0	14	Pa	0.1 – 1100 hPa to 0.1 hPa
101	**Temperature**	**0 12 001**	1	0	12	K	150 – 350K to 0.1 K
102	**Specific humidity**	**0 13 001**	5	0	14	$kg.kg^{-1}$	0 – 50 $g.kg^{-1}$ to 0.01 $g.kg^{-1}$
103	**Estimated error in pressure**	**New**	-1	0	14	Pa	0.1 – 1100 hPa to 0.1 hPa
104	**Estimated error in temperature**	**New**	1	0	12	K	150 – 350K to 0.1 K
105	**Estimated error in specific humidity**	**New**	5	0	14	$Kg.kg^{-1}$	0 – 50 $g.kg^{-1}$ to 0.01 $g.kg^{-1}$
106	**Percent confidence**	**0 33 007**	0	0	7	%	0 = bad, 100 = good
	(end delayed replication – number of step 2B samples)						

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Two main questions

1. Which bits in the old flag table are currently used by NWP centres?

2. Do we keep the Level 2b (1D-Var) data in the new BUFR?

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