BUFR format in a nutshell

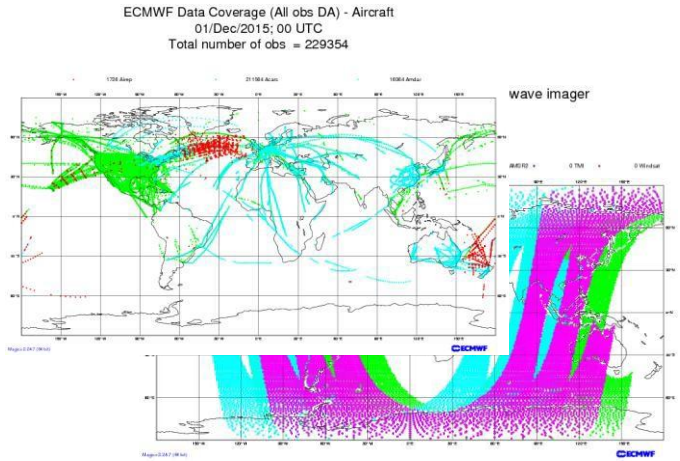
Marijana Crepulja

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marijana.crepulja@ecmwf.int

ECMWF

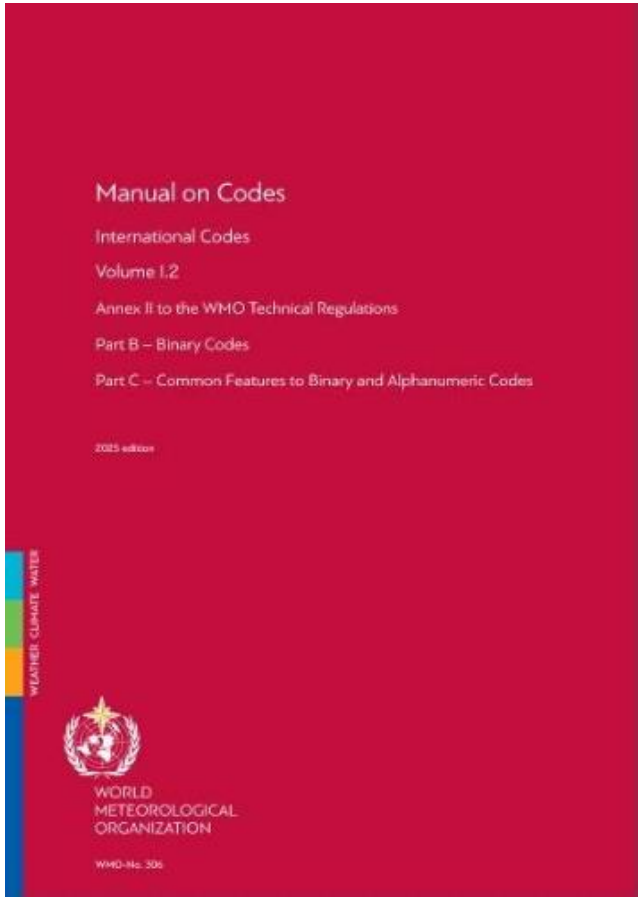
BUFR - WMO binary code



- BUFR (Binary Universal Form for the Representation of meteorological data) is
  - a flexible binary format
  - mainly used to encode in situ and satellite observations
  - can also represent forecast data.

- Self descriptive code and machine independent.
- Table driven

WMO Manual on Codes



- Fully describes BUFR coding standards
- It is publicly accessible on the WMO web site

https://community.wmo.int/site/knowledge-hub/programmes-and-initiatives/wmo-information-system-wis/about-manual-codes-volume-i2

- A new version of the tables which are part of the manual is released externally by WMO twice a year.

- WMO Expert Team on Data standards maintains and develops the manual https://github.com/wmo-im/et-data

BUFR message

Continuous bit stream made of sequence of octets.



BUFR tables

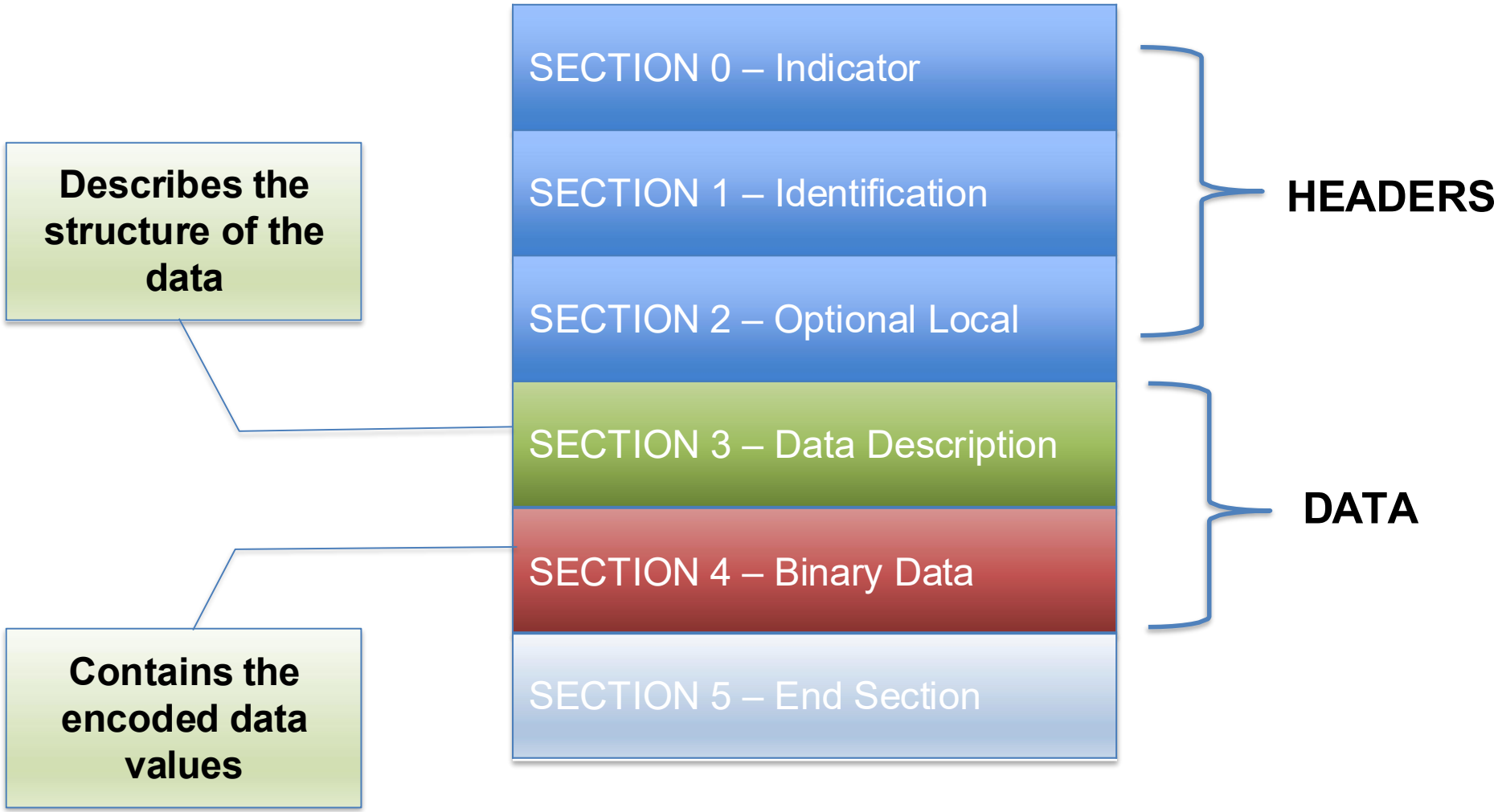
- To decode a **BUFR** message, we need to know how to parse the *bit stream* contained in the message. To do so, we need the **WMO BUFR** tables.
- A *bit stream* is a sequence of octets (1 octet=8 bits).
- **ecCodes** includes the **WMO BUFR** tables.
- There are 4 tables

TABLE	CONTENTS
TABLE A	Data category (surface data/ Radar Data….)
TABLE B	Contains the BUFR keys (elements)
TABLE C	Operators
TABLE D	BUFR Common Sequences (templates)

- Latest version of the tables is accessible in several formats from the WMO web site

https://community.wmo.int/site/knowledge-hub/programmes-and-initiatives/wmo-information-system-wis/about-manual-codes-volume-i2/latest-version

BUFR structure



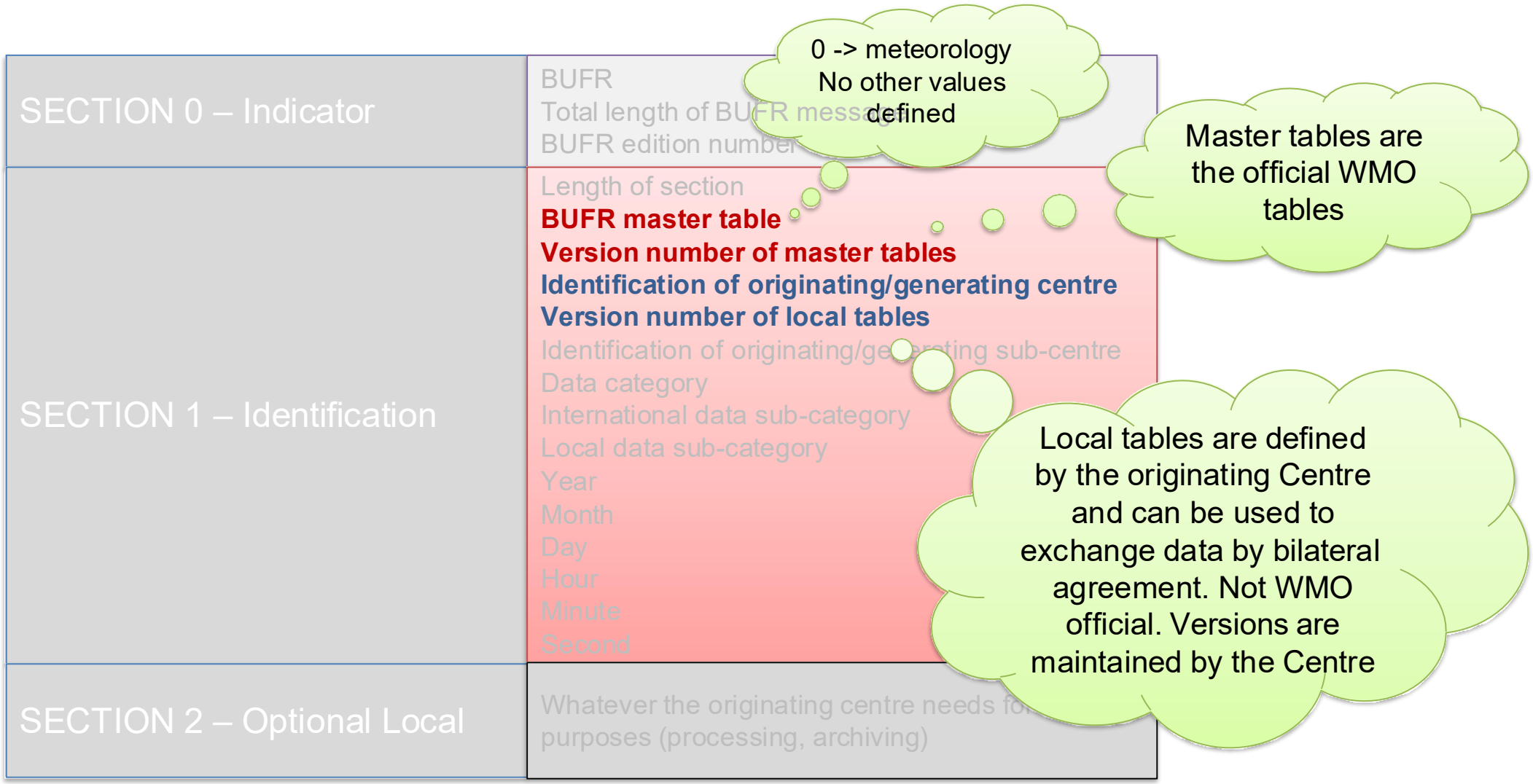
BUFR headers

SECTION 0 – Indicator	BUFR Total length of BUFR message BUFR edition number
SECTION 1 – Identification	Length of section BUFR master table Version number of master tables Identification of originating/generating centre Version number of local tables Identification of originating/generating sub-centre Data category International data sub-category Local data sub-category Year Month Day Hour Minute Second
SECTION 2 – Optional Local	Whatever the originating centre needs for internal purposes (processing, archiving)

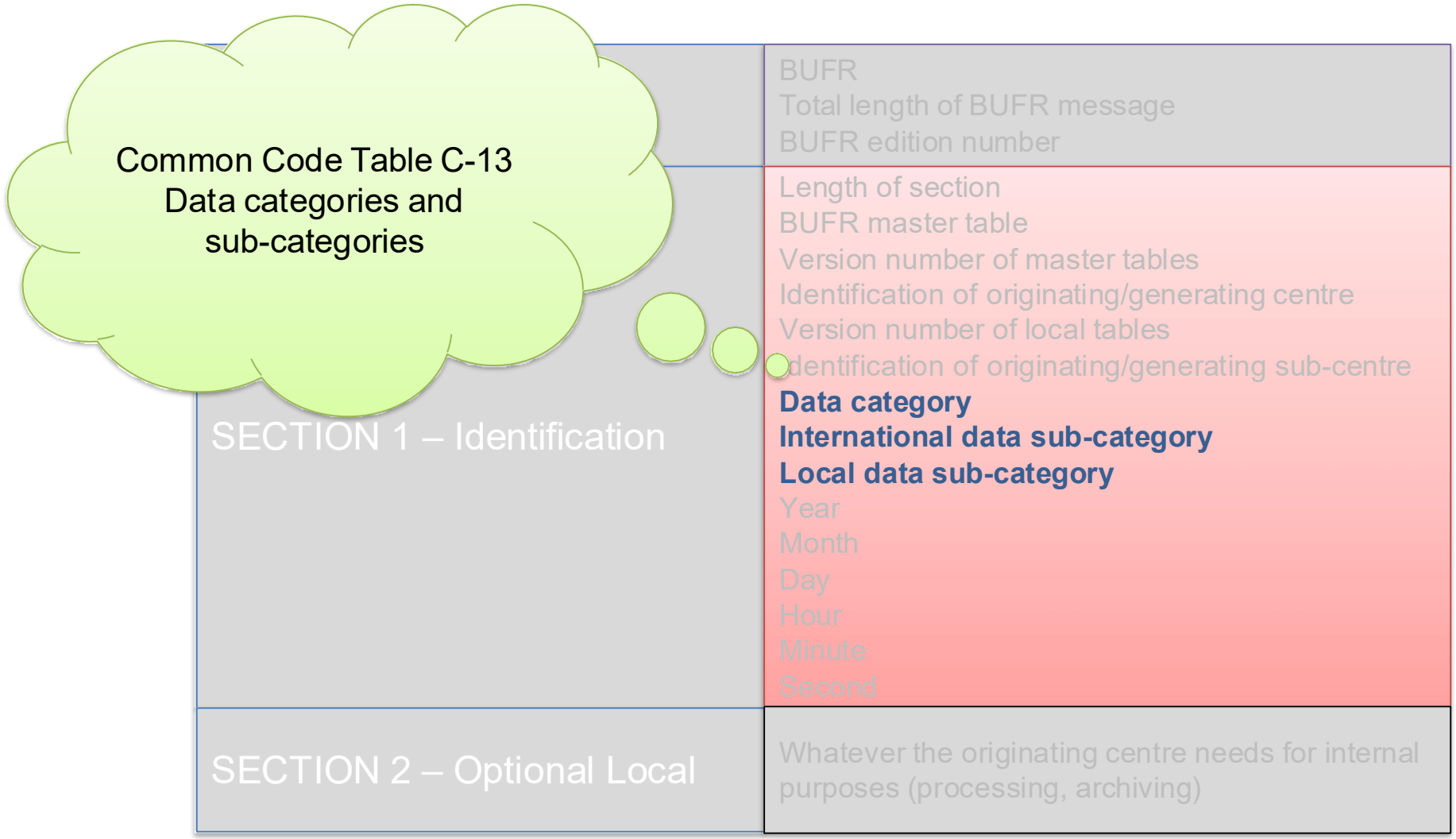
What info is important to have before decoding BUFR message and how we can find it?



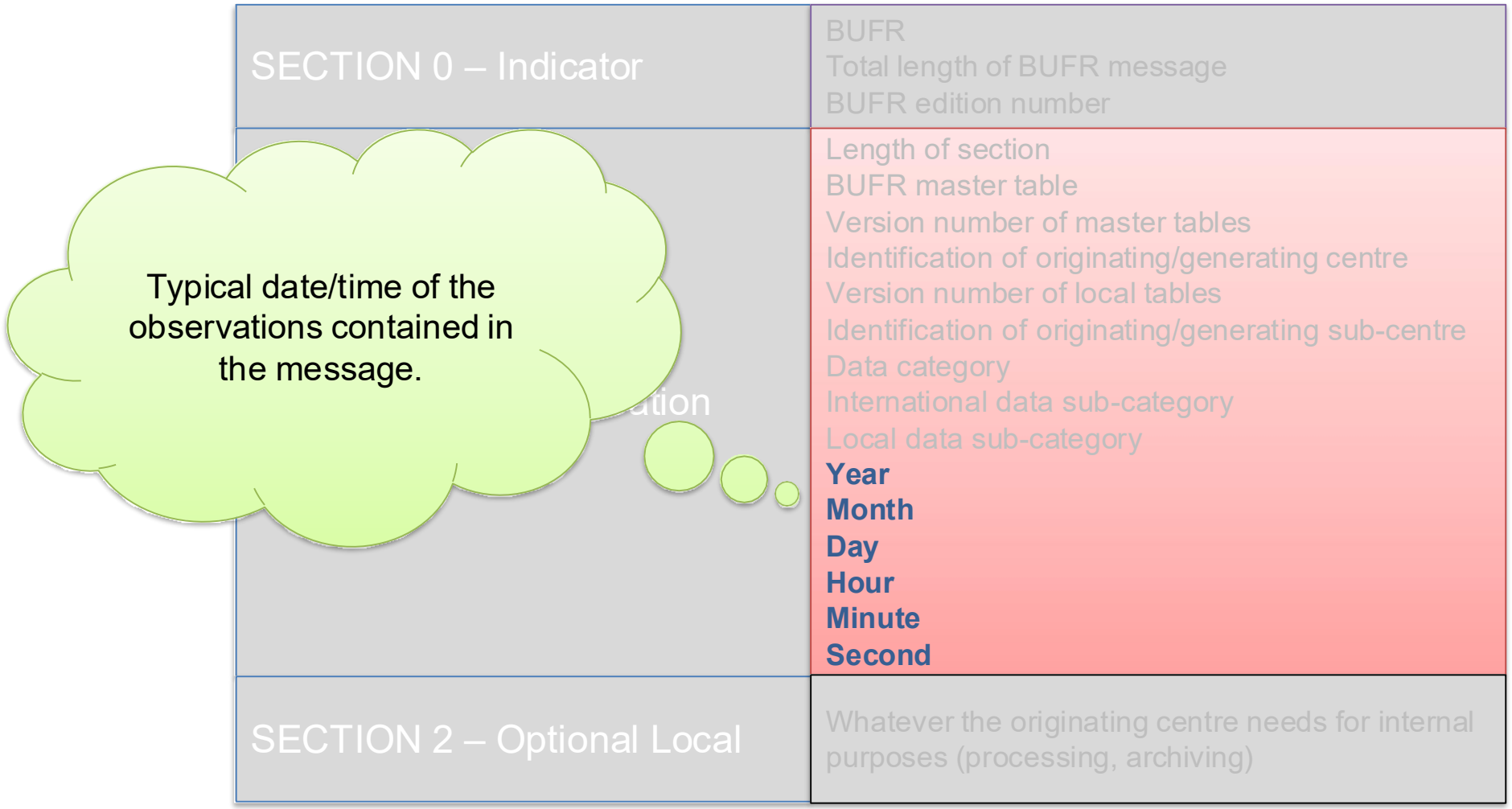
Which BUFR tables?



BUFR data category



BUFR date/time



BUFR Data section (sections 3 and 4)

- Contains the Data description section (recipe) and the binary data (ingredients).

Section 3 : Data Description Section

```
309007,222000,101000,31002,31031,
1031,1032,101000,31002, 33007
```

Descriptors





Binary data (bit stream)

Section 4 : Data section

```
10010001110001111110010001100010001000
00011000010001000100010000100001000010000
```



BUFR Message



BUFR Table B (descriptors starting with 0)

encoding parameters

meaning

Elements descriptors

Class 12 – BUFR/CREX Temperature

TABLE REFERENCE F X Y	ELEMENT NAME	BUFR UNIT	BUFR SCALE	BUFR REFERENCE VALUE	BUFR DATA WIDTH (Bits)	CREX UNIT	CREX SCALE	CREX DATA WIDTH (Characters)
0 12 001	Temperature/air temperature	K	1	0	12	°C	1	3
0 12 002	Wet-bulb temperature	K	1	0	12	°C	1	3
0 12 003	Dewpoint temperature	K	1	0	12	°C	1	3
0 12 004	Air temperature at 2 m	K	1	0	12	°C	1	3
0 12 005	Wet-bulb temperature at 2 m	K	1	0	12	°C	1	3
0 12 006	Dewpoint temperature at 2 m	K	1	0	12	°C	1	3
0 12 007	Virtual temperature	K	1	0	12	°C	1	3
0 12 011	Maximum temperature, at height and over period specified	K	1	0	12	°C	1	3
0 12 012	Minimum temperature, at height and over period specified	K	1	0	12	°C	1	3
0 12 013	Ground minimum temperature, past 12 hours	K	1	0	12	°C	1	3
0 12 014	Maximum temperature at 2 m, past 12 hours	K	1	0	12	°C	1	3
0 12 015	Minimum temperature at 2 m, past 12 hours	K	1	0	12	°C	1	3
0 12 016	Maximum temperature at 2 m, past 24 hours	K	1	0	12	°C	1	3
0 12 017	Minimum temperature at 2 m, past 24 hours	K	1	0	12	°C	1	3
0 12 021	Maximum temperature at 2 m	K	2	0	16	°C	2	4
0 12 022	Minimum temperature at 2 m	K	2	0	16	°C	2	4
0 12 023	Temperature	°C	0	–99	8	°C	0	2
0 12 024	Dewpoint temperature	°C	0	–99	8	°C	0	2
0 12 030	Soil temperature	K	1	0	12	°C	1	3
0 12 049	Temperature change over specified period	K	0	–30	6	°C	0	2
0 12 051	Standard deviation temperature	K	1	0	10	°C	1	3
0 12 052	Highest daily mean temperature	K	1	0	12	°C	1	3

Significance qualifier Code table

0-08-021 Time significance

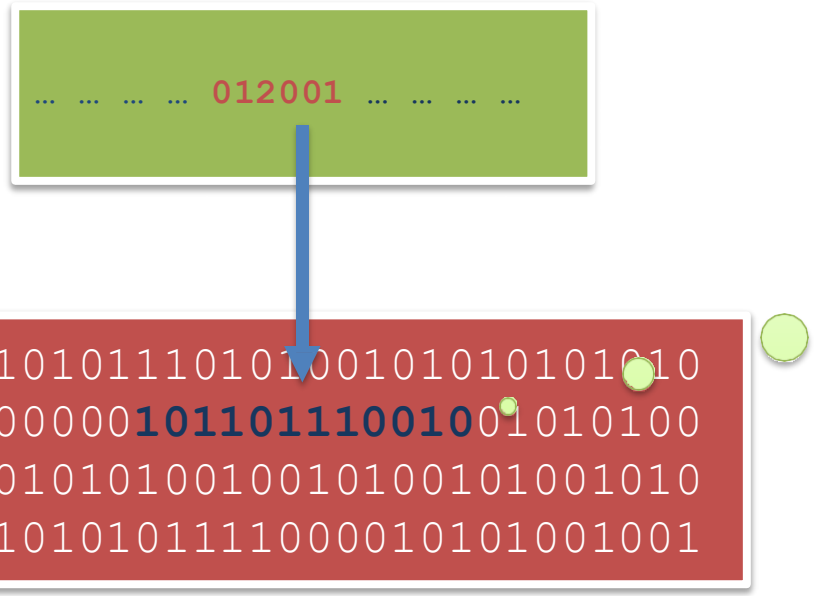
0	Reserved
1	Time series
2	Time averaged (see Note 1)
3	Accumulated
4	Forecast
5	Forecast time series
6	Forecast time averaged
7	Forecast accumulated
8	Ensemble mean (see Note 2)
9	Ensemble mean time series
10	Ensemble mean time averaged
11	Ensemble mean accumulated
12	Ensemble mean forecast
13	Ensemble mean forecast time series
14	Ensemble mean forecast time averaged
15	Ensemble mean forecast accumulated
16	Analysis
17	Start of phenomenon
18	Radiosonde launch time
19	Start of orbit
20	End of orbit
21	Time of ascending node
22	Time of occurrence of wind shift
23	Monitoring period
24	Agreed time limit for report reception
25	Nominal reporting time
26	Time of last known position
27	First guess
28	Start of scan
29	End of scan or time of ending
30	Time of occurrence
31	Missing value

BUFR decoding formula

$$value = (intValue + Reference)\ 10^{-scale}$$

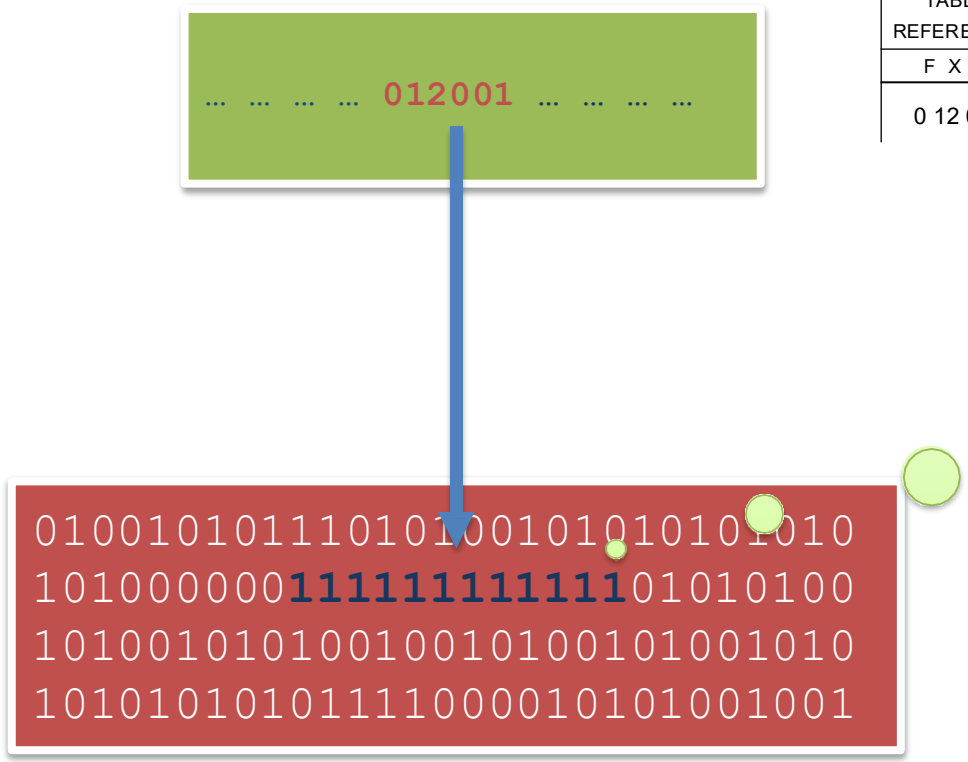
Class 12 – BUFR/CREX Temperature

TABLE REFERENCE F X Y	ELEMENT NAME	BUFR UNIT	BUFR SCALE	BUFR REFERENCE VALUE	BUFR DATA WIDTH (Bits)
0 12 001	Temperature/air temperature	K	1	0	12



(2930 + 0) * 10^{-1} = 293.0 K

BUFR missing value

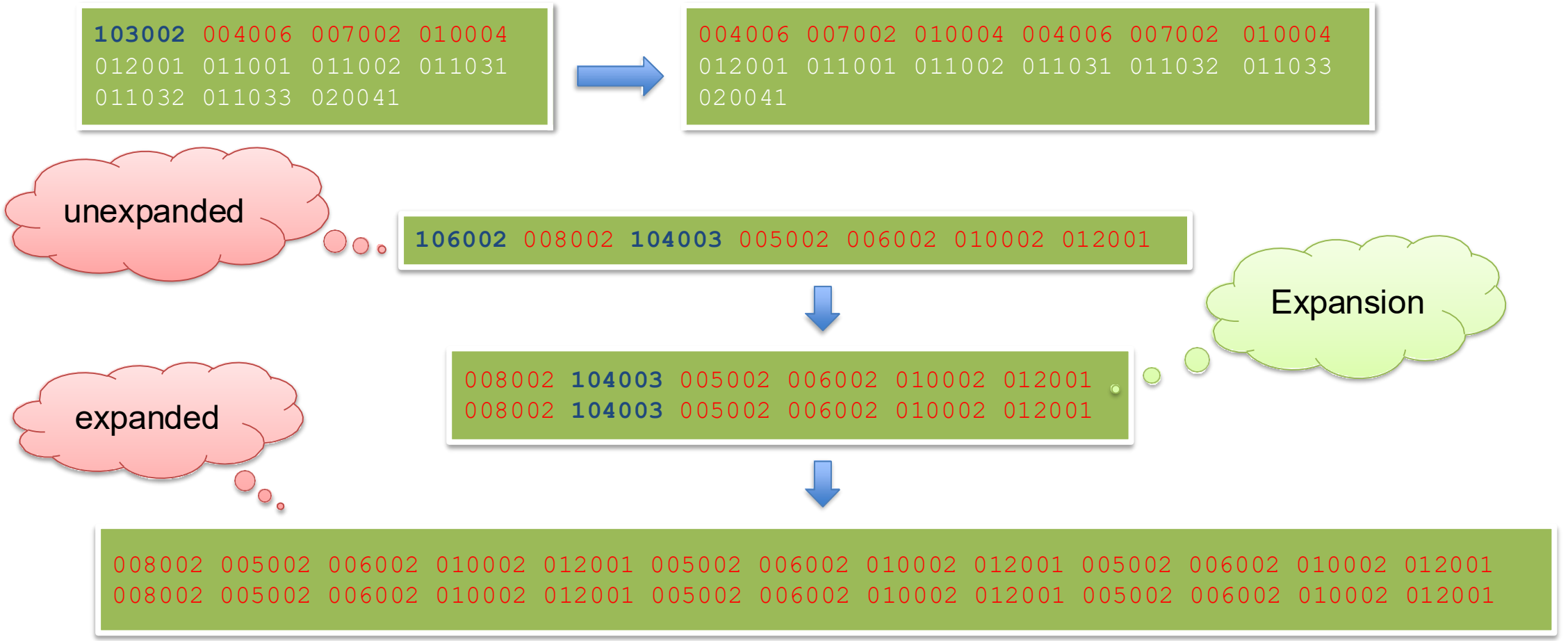


Class 12 – BUFR/CREX Temperature

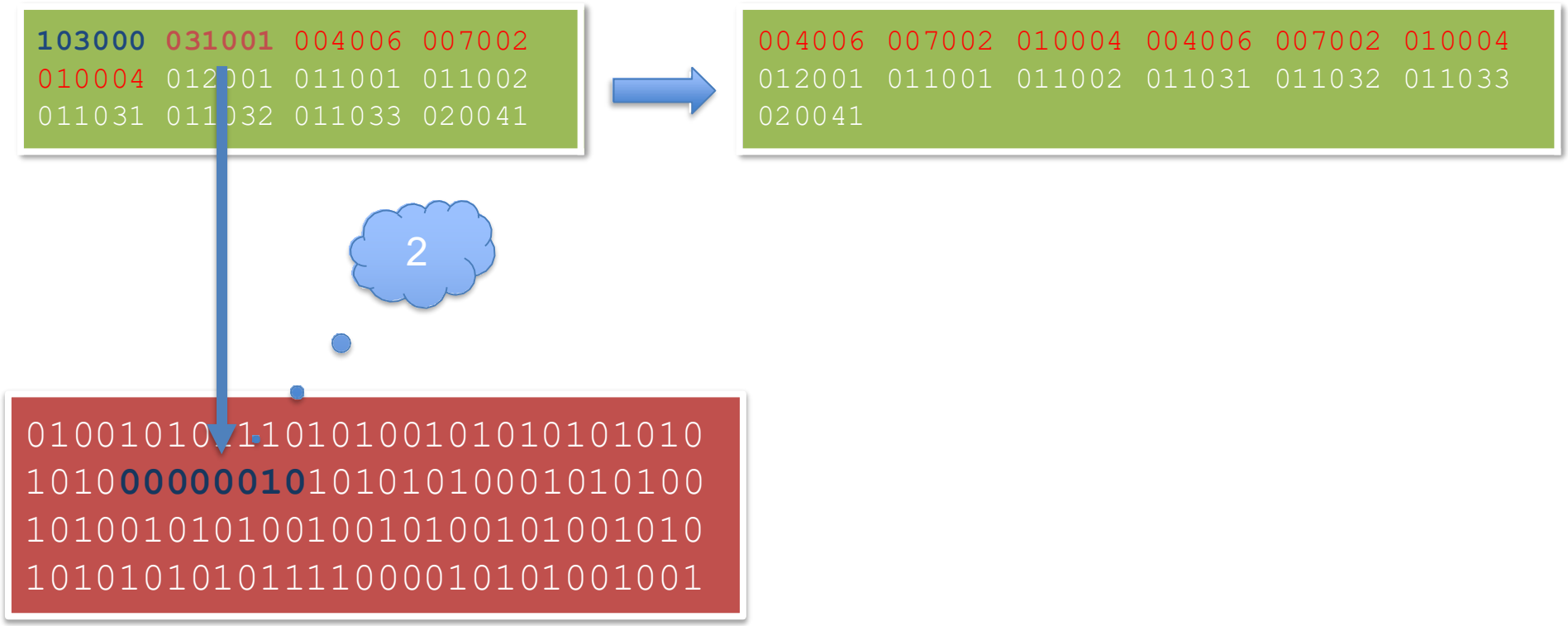
TABLE REFERENCE F X Y	ELEMENT NAME	BUFR UNIT	BUFR SCALE	BUFR REFERENCE VALUE	BUFR DATA WIDTH (Bits)
0 12 001	Temperature/air temperature	K	1	0	12

All bits set to 1 = missing value

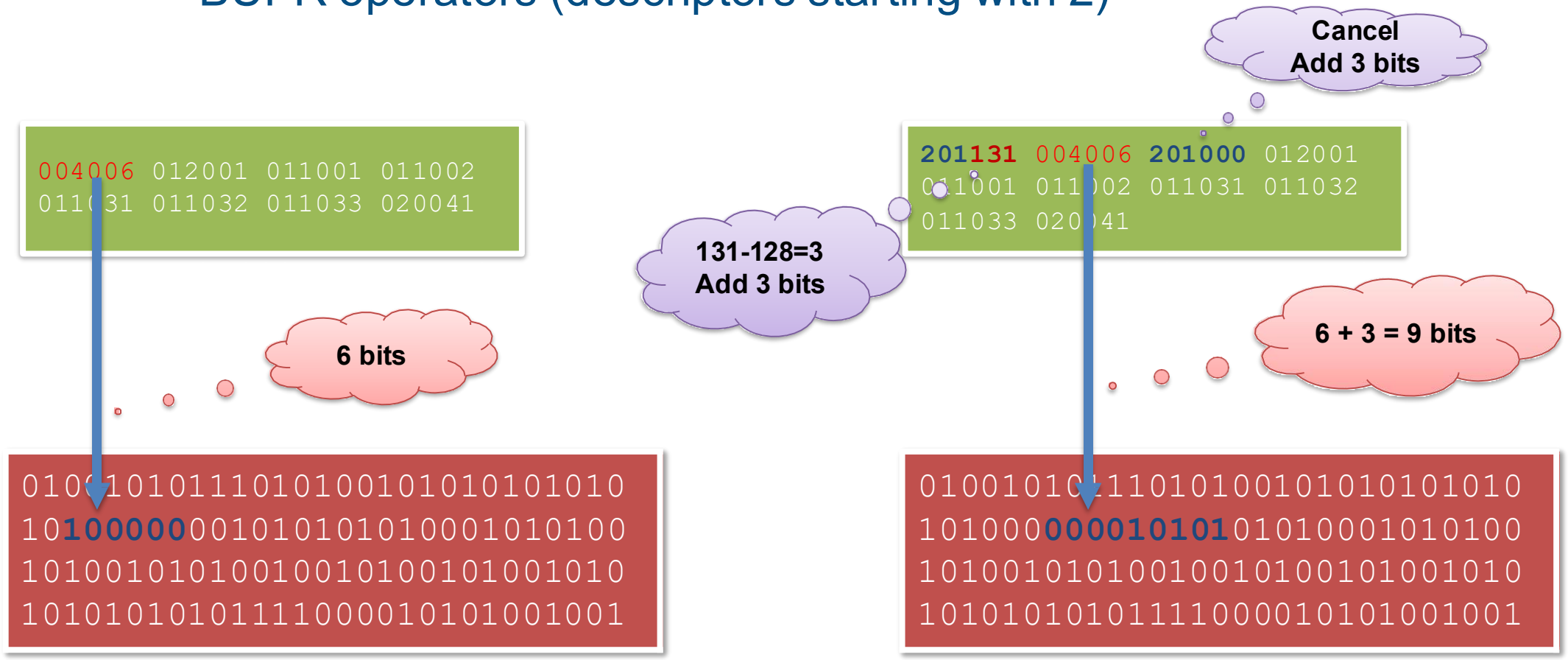
BUFR replication (descriptors starting with 1)



BUFR delayed replication (descriptors starting with 1)



BUFR operators (descriptors starting with 2)



BUFR Table D (descriptors starting with 3)

Sequence description

Sequence descriptor

TABLE REFERENCE F X Y	TABLE REFERENCES	ELEMENT NAME
		(Sequence for representation of TEMP, TEMP SHIP and TEMP MOBIL observation type data)
3 09 052	3 01 111	Identification of launch site and instrumentation for P, T, U and wind measurements
	3 01 113	Date/time of launch
	3 01 114	Horizontal and vertical coordinates of launch site
	3 02 049	Cloud information reported with vertical soundings
	0 22 043	Sea/water temperature
	1 01 000	Delayed replication of 1 descriptor
	0 31 002	Extended delayed descriptor replication factor
	3 03 054	Temperature, dewpoint and wind data at a pressure level with radiosonde position
	1 01 000	Delayed replication of 1 descriptor
	0 31 001	Delayed descriptor replication factor
	3 03 051	Wind shear data at a pressure level with radiosonde position

In section 3 is equivalent to the list of descriptors

List of descriptors. It can contain sequence descriptors

Names of the descriptors in the sequence

Resources

Videos:

- https://www.youtube.com/watch?v=Xf2YuIzVS7g
- https://www.youtube.com/watch?app=desktop&v=d-iiVT2XxTw
- https://www.youtube.com/watch?v=xQx2214buVU

ECMWF training pages:

- https://learning.ecmwf.int/mod/scorm/player.php?a=176&currentorg=Introduction_to_BUFR_decoding_with_ecCodes_ORG&scoid=452

ecCodes confluence:

- https://confluence.ecmwf.int/display/ECC/ecCodes+Home


thank you
danke
謝謝
ngiyabonga
рахмат
teşekkür ederim
спасибо
gracias
obrigado
merci
bedankt
dziękuje
go raibh maith agat
mochchakkeram
sukriya
kop khun krap
terima kasih
dakujem
arigatô
grazie
takk
tack
dank je
tapadh leat
Баярлалаа
faafetai lava
kiitos
dankie
dhanyavad
hvala
mauruuru
köszönöm
enkosi
sobodi
děkuji
mèsi
sagolun
didi madloba
kam sah hamnida
তোমাকে ধন্যবাদ
감사합니다
xièxie
ευχαριστώ
rahmat
najis tuke
rahmet
tanemirt
ありがとう
diolch
dhanyavadagalu
shukriya
merci
мерси
trugarez
chokrane
murakoze
tenki
asante
manana
obrigada
хвала
mamnun
дякую
djiere dieuf
tau
akun
dankon
aciú
sulpáy
gràcies
gratias ago
chnorakaloutioun
vinaka
спасибі
blagodaram
misaotra
matondo
paldies
grazzi
mahalo
barka
welalin
mersi
kia ora
spas
ngiyabonga

Next session: Example data access

- Global Upper Air Radiosonde BUFR archive from ECMWF

  → **Search:** gov.noaa.ncdc:C01549

  → **Download:** Upperair-BUFR_ECMWF_d202201_c20250206.tar.gz (*1.7 GB*)



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