BUFR decoding

Dominique Lucas

User Support

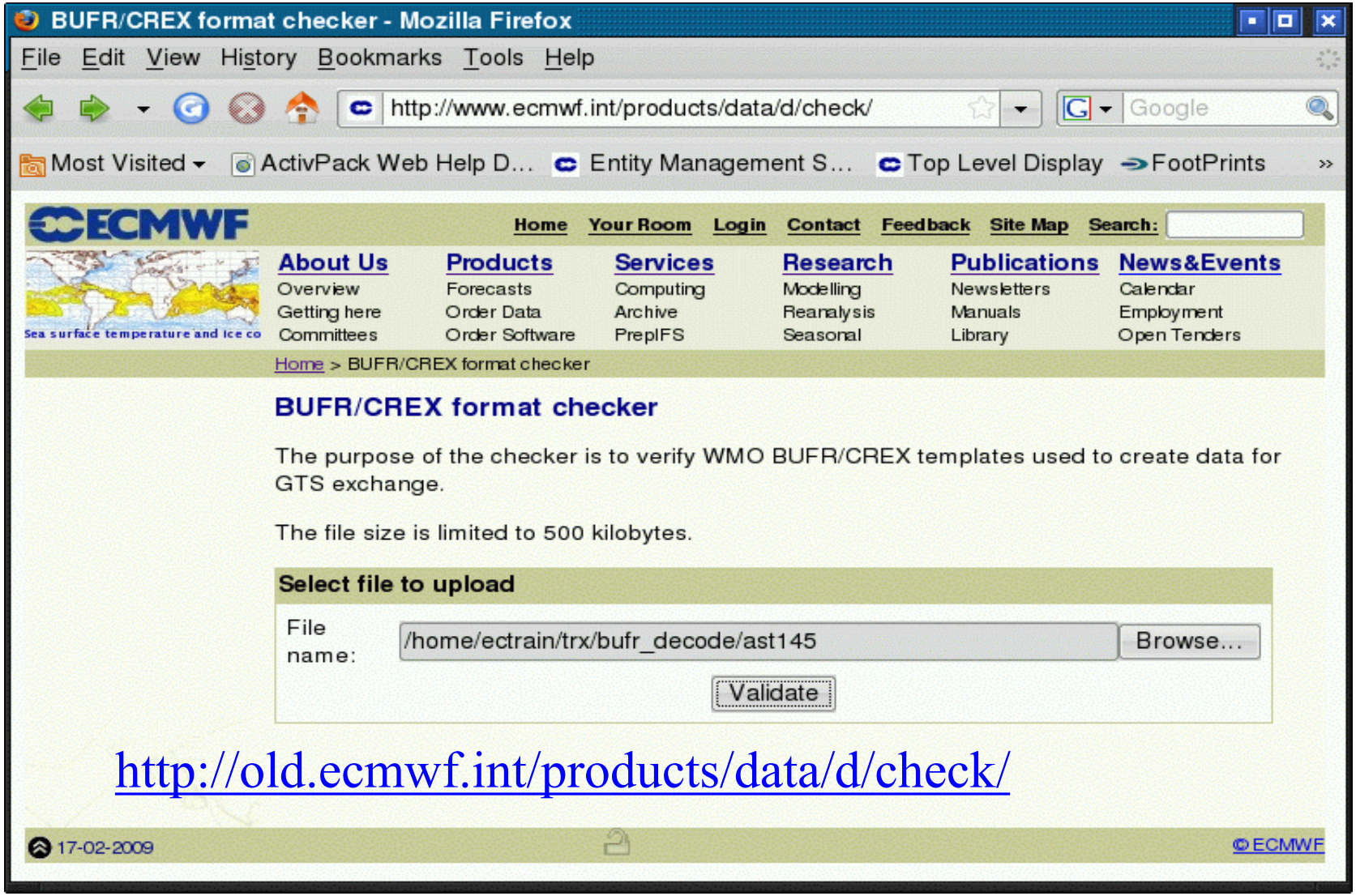
Content

- What is BUFR
- BUFR tools
- BUFR format
- BUFR decoding
- Practical examples

What is BUFR

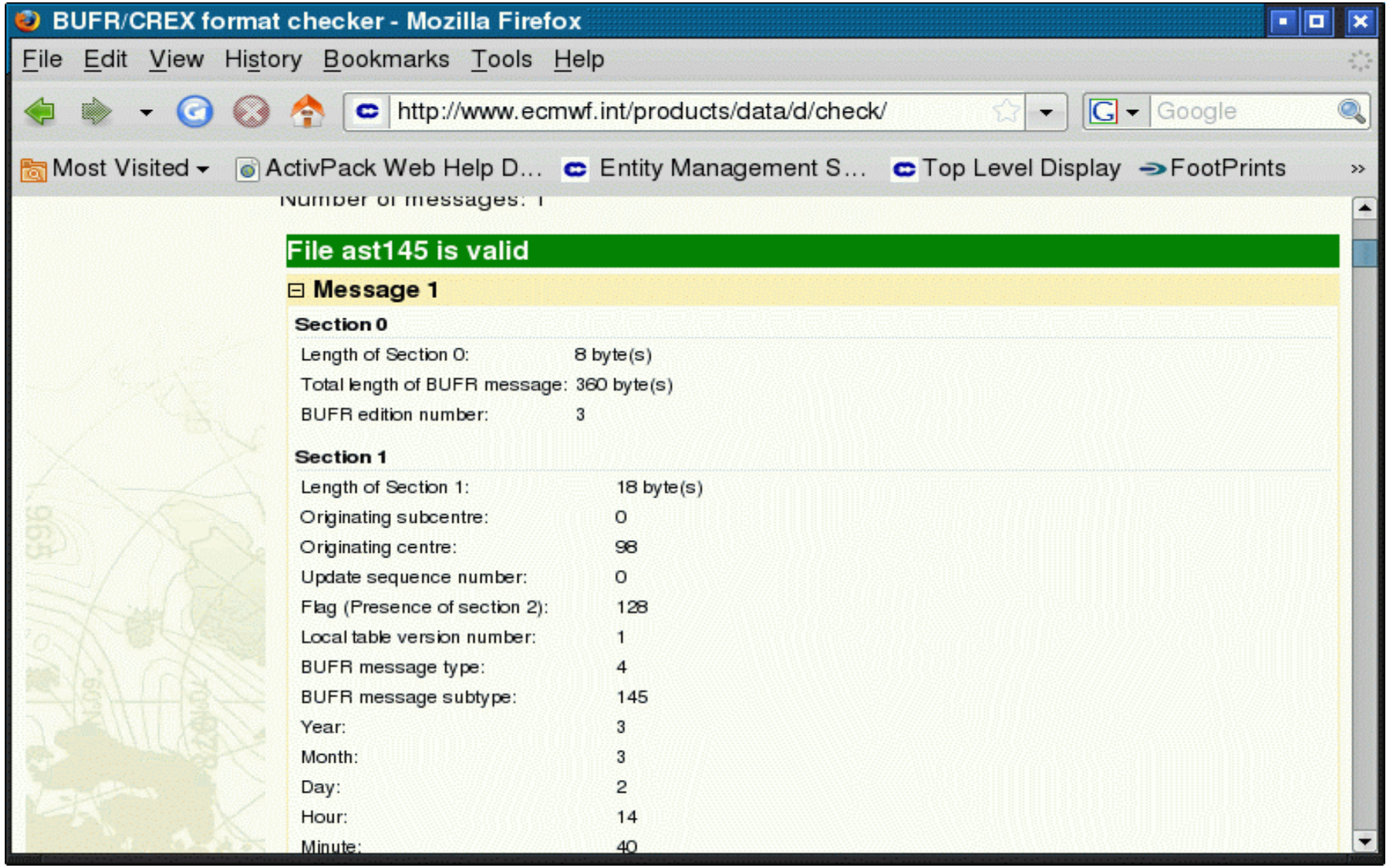
- Binary representation of meteorological data or Binary Universal Form for data Representation.
- Continuous bit stream made of sequence of octets.
- Table driven code.
- Self descriptive code.
- Machine independent.
- Compression available for improved transmission speed.

BUFR tools – data validation

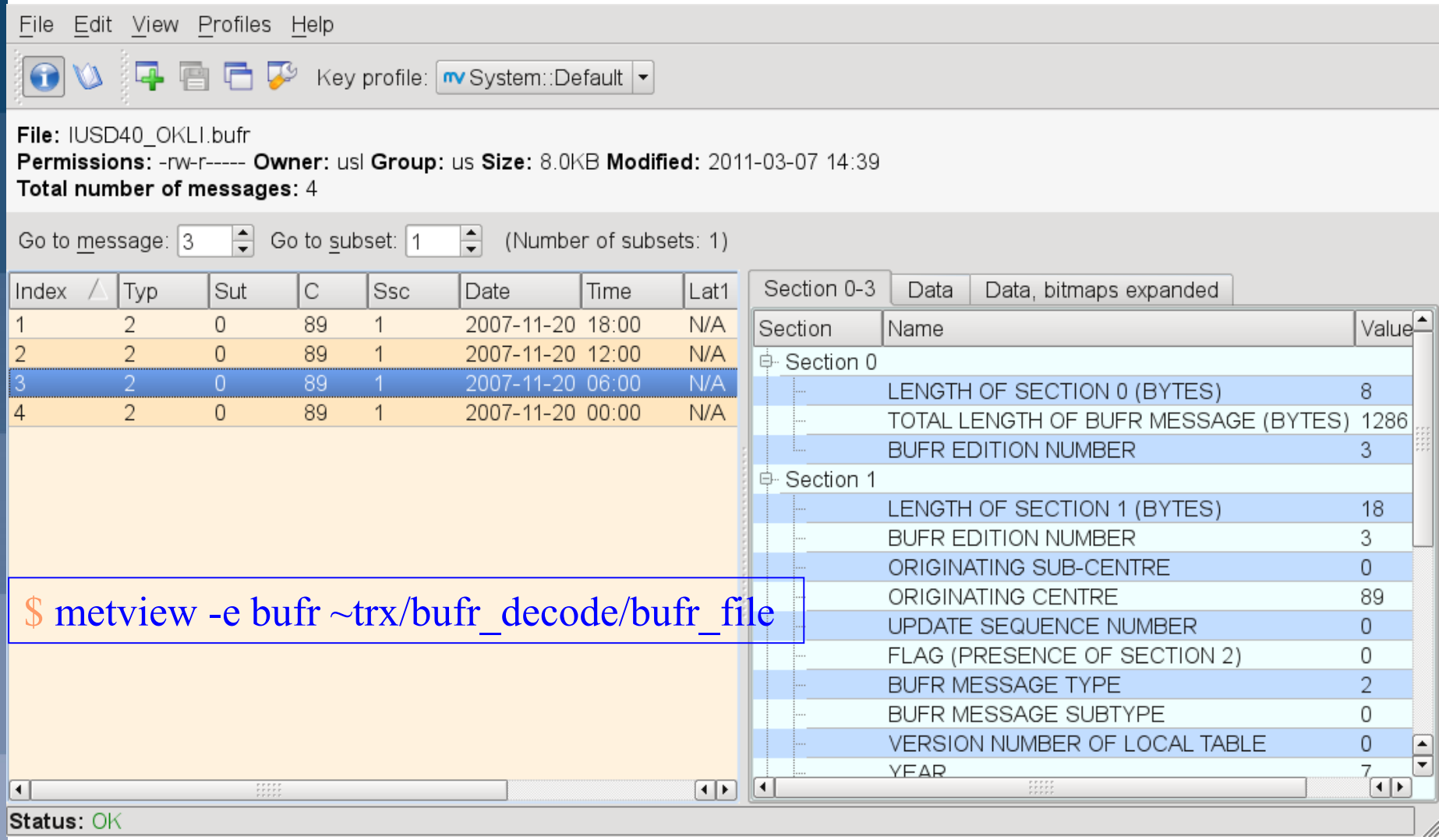


http://old.ecmwf.int/products/data/d/check/

BUFR tools – data validation



BUFR data examiner - metview4

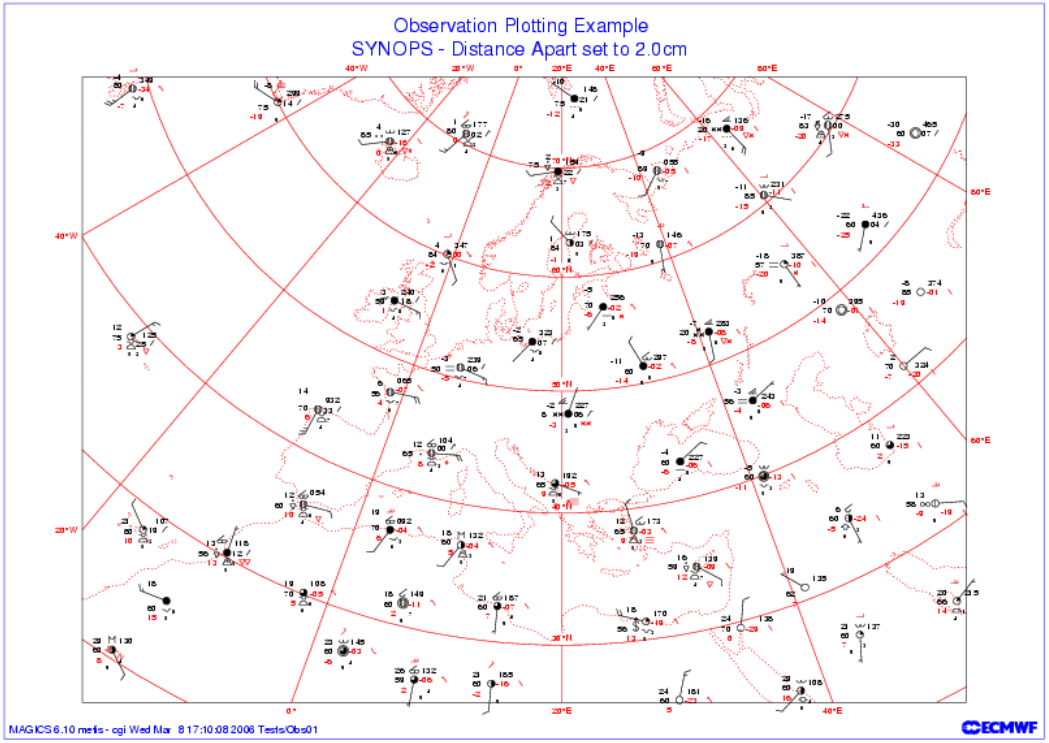


BUFR format

- Indicator section
- Identification section
- Optional section
- Data description section
- Data section
- End section
  - All sections are padded with “0”s if needed to occupy even number of octets.

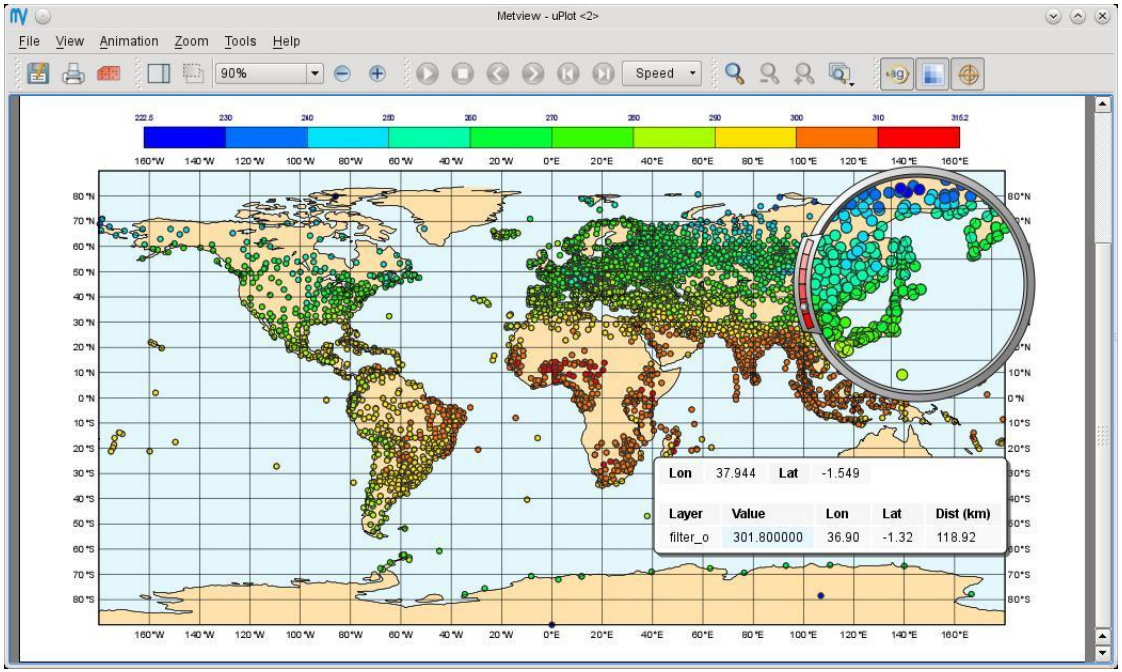
Section 0 - Indication section

- 4 characters ‘BUFR’
- Length of message
- Edition Number



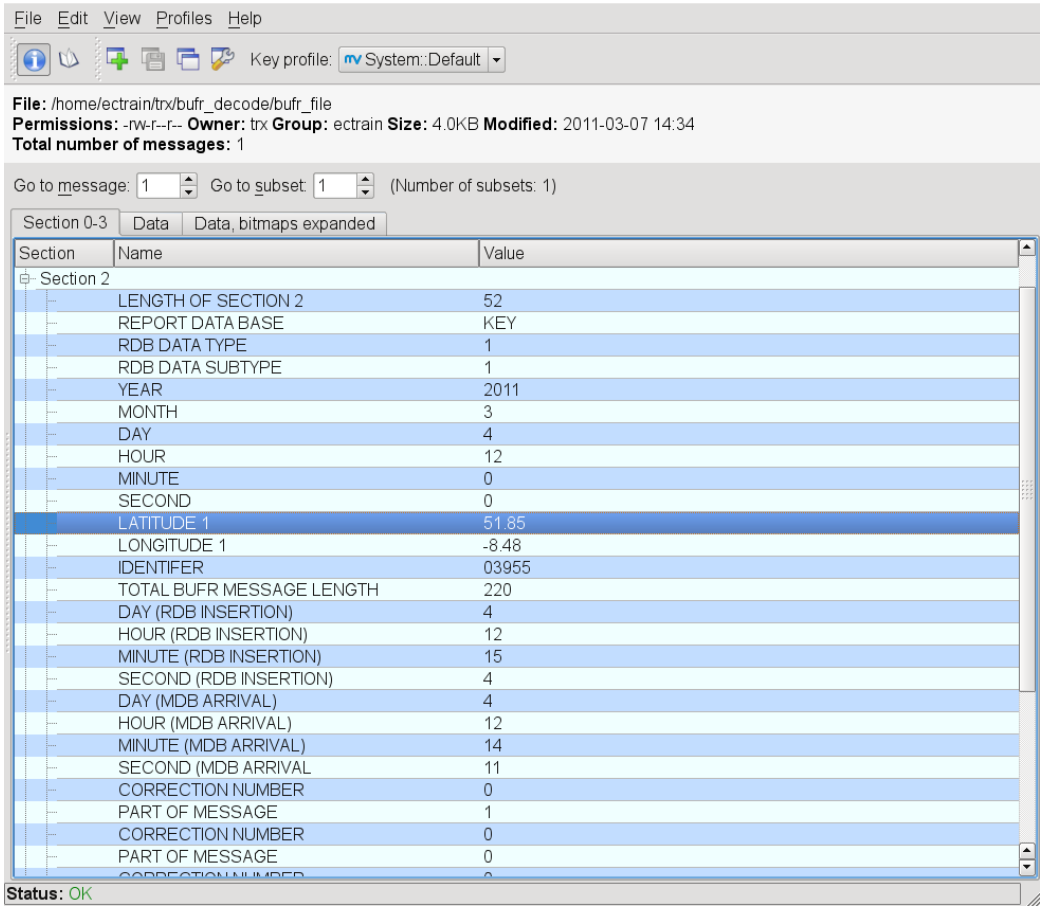
Section 1 - Identification section

- Originating Centre
- Data Category (Table A) and sub-category
- Version number of tables
- Date and time



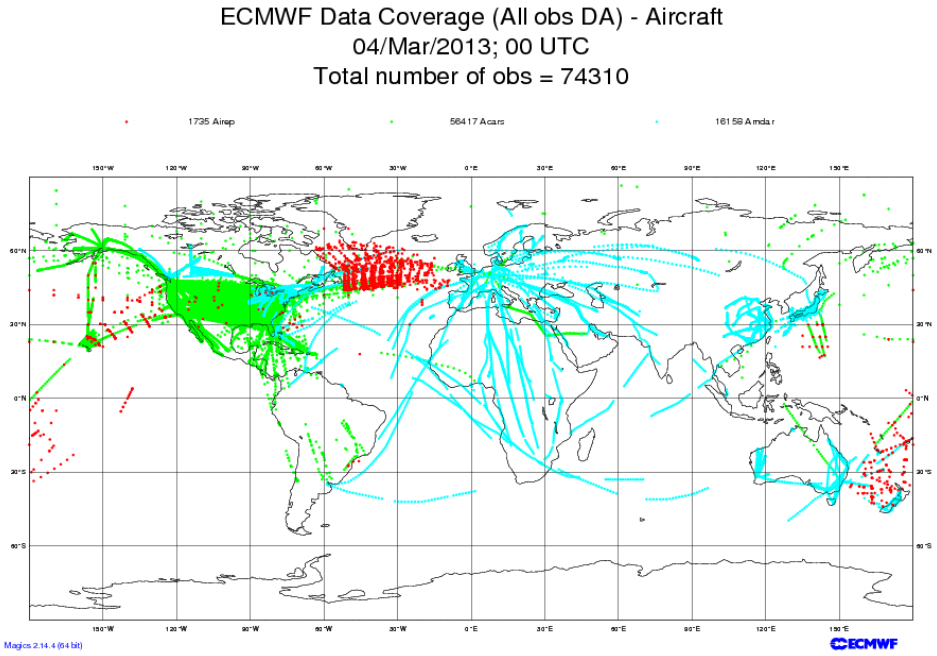
Section 2 – Optional section

- At ECMWF, section 2 contains data used by MARS.



Section 3 – Data description section

- Number of data subsets
- Flag for compression
- Data descriptors



Section 3 – Data descriptors

F type	X category	Y entry
2 bits	6 bits	8 bits

- F = 0 Element Descriptor – Bufr table B
- F = 1 Replication descriptor
  - X = number of descriptors to repeat
  - Y = number of times the descriptors are repeated
- F = 2 Operator Descriptor – “Internal table C”
- F = 3 Sequence Descriptor – Bufr table D

“Table C” - Data Descriptor operators

- 201yyy - Change data width
- 202yyy - Change scale
- 203yyy - Change reference value

- 222000 - Quality information

This table is internal to the BUFR software.
See:
http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/LatestVERSION/LatestVERSION.html

Section 4 - Data section

- Binary data

Section 5 - End section

- 4 digits ‘7777’

BUFR Tables

- Table A - Data category
- Table B - Classification of elements
- Table C - Code and flag table (*)
- Table D - List of common sequences

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

(*) Not to mix with the table C with ‘data descriptor operators’ mentioned before.

Table A - Data category

- Used in the Section 1 (element 9) of the BUFR message
- Example:

Code figure	Meaning
0	Surface data - land
1	Surface data – sea
2	Vertical soundings (not satellite) …
31	Oceanographic data

Table B - Classification of elements

Element Name	Unit	Scale	Reference	#bits
005001 Latitude (high accuracy)	Degree	5	-9000000	25
007003 Geopotential	m**2/s**2	-1	-400	17
002019 Satellite instruments	Code table	0	0	11
008001 Vertical sounding signifi	Flag Table	0	0	7
001006 Aircraft flight number	CCITTIA5	0	0	64
011012 Wind speed at 10m	m/s	1	0	12

- (obs. * 10**scale – Reference) is encoded into #bits bits
- For coded or flagged values, the element descriptor indicates the number of the table describing the codes/flags.

- 0 - Table B entry
  - 05 - Location (horizontal 1) class
  - 01 - Identification
  - 08 - Significance qualifiers

Table C – Code and flag tables

- 0 20 003 – Present Weather

Code figure	Meaning
0	Cloud development not observed or not observable
1	Clouds generally dissolving or becoming less developed
…	
10	Mist
11	Patches of shallow fog or ice fog
…	
61	Rain, not freezing, continuous; slight at time of obs.
…	
171	Snow, slight
172	Snow, moderate
173	Snow, heavy
…	
511	Missing

Table D - List of common sequence

- Table D can contain sequences of table B entries, Table D entries and Operators. It is not needed but saves a lot of space.

  - 301027 301001 WMO block and station
    002011 Radiosonde type
    002012 Radiosonde computational method
    301011 Date
    301012 Time
    301022 Lat/Long and station height

Bufr software

- PBIO routines
  - PBOPEN - open bufr file for read/write
  - PBBUFR - read bufr message
  - PBWRITE - write bufr message

```
!
!     Open input file for reading.
!
      CALL PBOPEN (KUNIT, INPUT_FILE, OPEN_MODE, ISTATUS)
!
!     Check return code.
!
      WRITE ( * , * ) ' '
      WRITE ( * , * ) 'BFDEMO: After PBOPEN, status code   = ', ISTATUS
      WRITE ( * , * ) ' '
      IF (ISTATUS .NE. 0) THEN
          CALL PBCLOSE (KUNIT, ISTATUS)
          STOP 'BFDEMO: PBOPEN failed.'
      END IF
!
!     This is the beginning of a loop through BUFR records
!     reading one field at a time from the input datafile.
!
LOOP: DO WHILE (.TRUE.)
!
         WRITE ( * , * ) '************************************************'
         WRITE ( * , * ) ' '
         CALL PBBUFR (KUNIT, KBUFF, JBUFL * NBYTES_SP, KBUFL, ISTATUS)
         WRITE ( * , * ) 'BFDEMO: After PBBUFR, status code   = ', ISTATUS
!
```

BUFR decoding - BUFREX

- CALL BUFREX (kbufl, kbuff, ksup, ksec0,
  ksec1, ksec2, ksec3, ksec4,
  kelem, cnames, cunits, kvals,
  values, cvals, kerr)
- Input arguments
  - kbufl - length of bufr message in words
  - kbuff - array containing bufr message
  - kelem - expected number of expanded elements
  - kvals - size of values array

BUFR decoding - BUFREX

- Output arguments
  - ksup - array containing supplementary information
  - ksec[0-4] - array containing section [0-4] information
  - cnames - character array containing element names
  - cunits - character array containing element units
  - values - real array containing element values
  - cvals - character array containing char. elem. values
  - kerr - return code

BUFR decoding – BUSEL (expanded descriptors)

- CALL BUSEL(KTDLEN,KTDLST,KTDEXL,KTDEXP,KERR)

  Output arguments

  – KTDLEN - An INTEGER variable containing number of data descriptors in KTDLST array

  – KTDLST - An INTEGER array containing the list of KTDLEN data descriptors

  – KTDEXL - An INTEGER variable containing number of expanded data descriptors

  – KTDEXP - An INTEGER array containing the list of KTDEXL data descriptors

  – KERR - An INTEGER containing error

BUFR decoding

- To access character strings from cvals array, say, for element i.
  - index = values(i)/1000
  - string = cvals(index)
  - values(i) = index * 1000 + length

  For example, if values of a character descriptor is 2008, one will have to look at cvals(2) and the string will be 8 characters long.

- To access i-th element in multi subset message from values array
  - index = i +(nsub-1) * kelem

BUFR Tables

- BUFR Edition 4 (and 3) naming convention
  - vssswwwwwxxxxxyyyzzz

v	- Bufr table (B, C, D)
sss	- Master table number (000)
wwwww	- Originating subcentre
xxxxx	- Originating centre
yyy	- Version number of master table used
zzz	- Version number of local table used

e.g. B0000000000098013001.TXT
C0000000000098013001.TXT
D0000000000098013001.TXT

Where to find more about BUFR

- WMO manual on Codes, Volume I, International Codes, Part B - Binary Codes, WMO No.306, FM-94-IX Ext BUFR
- BUFR User Guide and Reference Manual, ECMWF 2008

  https://software.ecmwf.int/wiki/display/BUFR/BUFRDC+Home
- Guides to WMO Table Driven Code Forms

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

  http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/LatestVERSION/LatestVERSION.html
- Python interface to BUFR available from KNMI

  https://code.google.com/p/pybufr-ecmwf/

BUFR decoding - the future …

- ecCodes: rewrite of “BUFREX”
  - More similar to the GRIB API
  - Fortran 90, C and python interface
  - BUFR tools
  - Conversion to json
- To be beta-released shortly

Practical examples – to be run on ecgate

- Copy files across …

  $ cd $SCRATCH

  $ tar xvf ~trx/bufr_decode/practicals.tar

  $ cd bufr_decode

- Familiarise yourself with the bufr examinar in metview, e.g.

  $ metview -e BUFR bufr_file

- The script “Retrieve_decode_bufr.cmd” decodes a BUFR Synop message. The source code file ‘bfdemo.f90’ is also available together with the Makefile. The file ‘bfdemo.c’ contains C code.

  $ make bfdemo

  $ ./bfdemo

Practical examples – to be run on ecgate

- Can you adapt the above script/code to write part of the observation data out to a file, e.g.

```
!  001001 WMO BLOCK NUMBER
!  001002 WMO STATION NUMBER
!  004001 YEAR
!  004002 MONTH
!  004003 DAY
!  004004 HOUR
!  004005 MINUTE
!  005001 LATITUDE (HIGH ACCURACY)
!  006001 LONGITUDE (HIGH ACCURACY)
!  010004 PRESSURE
!  011011 WIND DIRECTION AT 10 M
!  011012 WIND SPEED AT 10 M
```

An example job is available in Retrieve_extract_bufr.cmd. The source code file is bfextract.f90, with the Makefile:

```
$ make bfextract
$ ./bfextract
$ cat fort.2
```