

BUFRdisplay USER GUIDE

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Applies to BUFRdisplay v0.8.2 and subsequent.

BUFRdisplay is a program to:

- Examine the contents of BUFR-encoded files to see what data is included, as well as providing a detailed listing of the file structure.
- Decode and display BUFR files, as long as the data can be represented geographically.

Please note that BUFR is an all-encompassing format and there are certainly files which this program won't handle. **BUFRdisplay** which is under constant development so things will undoubtedly change. Please email me at vf0123@btinternet.com with any bugs, comments, or suggestions.

1. What Is BUFR?

First, a few words about BUFR files. If you would rather get on with using **BUFRdisplay**, skip to Section 3. However, this part does introduce some of the terminology used.

What exactly is BUFR? Standing for Binary Universal Form for the Representation of meteorological data, it is more properly known as the World Meteorological Organization (WMO) binary code FM 94 [3]. It was first approved by the MWO in 1988, and is widely used within the meteorological community. It apparently had the following design aims:

- The data contents would be self-defining (at least up to a point).
- Any form of data could be held.
- The file would use as little space as possible. To this end, extensive use is made of external tables which are used to expand "data definitions" within the file (which is why it is not completely self-defining). New data definitions can be added by updating the tables, rather than by changing the BUFR decoder itself. The data itself is encoded to use minimum space, as well as using built-in data compression. A consequence is that the file is just a string of binary 1s and 0s, and not text which could be human-read.

Whilst there are probably better and more general-purpose ways of doing all this now, BUFR, it seems, is here to stay. Unfortunately, BUFR seems to have been, and continues to be, modified over the years with a considerable number of extensions as particular facilities were found to be needed. This doesn't make the task of writing a decoder easy, as there are many special cases and exceptions to be taken into account if a complete job is to be done.

Some years ago, I decided to write some software to analyse the data definition part of the EUMETCast BUFR files to find out just what was in each one. The answer was quite surprising – there is often a lot more than one would expect. I emphasise that IANAM (I am not a meteorologist), so a lot of the data is over my head. Things like temperature, pressure, and wind speed I can understand - however, "parcel lifted index" is beyond me.

Once I learnt something about the file structure, I extended my program to decode the data into numbers suitable for processing by other software, and then added display facilities so that geographical data could be plotted on a map. Thus **BUFRdisplay** came into being.

2. BUFR File Basics

How is a BUFR file structured? I appreciate that this is not of general interest, but it shows where some of the terminology such as "message" and "subset" fits in.

- **BUFR file**

Consists of 1 or more **MESSAGES**.

- **MESSAGE**

Normally each message contains data in the same format, although there is nothing in BUFR which mandates this. **BUFRdisplay** assumes that they do, but will warn if this is not the case. I haven't yet found a file which doesn't.

A message is made up of:

- **HEADERS** (BUFR sections 0,1,2)

General information about the message.

- **DATA DESCRIPTORS** (BUFR section 3)

Define the data format.

A descriptor is a number of the form n-nn-*nnn*, e.g. 0-01-007. This is used to access a BUFR table, which in turn defines how the data is encoded and what units it is in. Some descriptors perform operations on the data, rather than simply describing data values.

- **SUBSETS** (BUFR section 4)

Hold the data as defined by the data descriptors.

There are one or more data subsets. Usually there are quite a few, e.g. a number of observations

The data can either be compressed or uncompressed. The vast majority of BUFR files broadcast by EUMETCast contain compressed data. A few use uncompressed data, notably the SYNOP and upper-air observations in the DWDSAT data.

There is an important difference in the internal BUFR structure which impacts on **BUFRdisplay**, depending on whether the data is compressed or uncompressed:

- For compressed data, each subset must have the same format, i.e. the fields (see below) must be the same for each subset.
- For uncompressed data, each subset can have a different format, i.e. the fields (see below) can vary for each subset.

BUFRdisplay can only display data if all subsets (and messages) have the same data format, and will warn if this is not the case. Most uncompressed files have different formats between subsets, and therefore cannot be displayed. However, they can be decoded for external processing. *This is something which I hope to address in a future release.*

- **DATA FIELDS/ELEMENTS** (BUFR section 4)

Note: this is terminology which I have introduced - it is not part of the BUFR specification.

Each subset consists of a number of **DATA FIELDS**, each field holding one **DATA ELEMENT** per subset.

A **DATA FIELD** corresponds to a data descriptor which is capable of holding data (not all are).

A **DATA ELEMENT** is the data contained within a data field, per subset. Thus each subset holds a row of data elements, one for each field.

So, conceptually, we have, where:

s = total number of subsets
n = total number of fields

SUBSETS	FIELDS			
	1	2	...	n
1	Value 11	Value 12	...	Value 1n
2	Value 21	Value 22	...	Value 2n
...				
s	Value s1	Value s2	...	Value sn

This only applies to BUFR files containing compressed data, fortunately the vast majority. For uncompressed data files, the number and meaning of fields can vary for each subset.

Data elements can be empty if the data is not available.

Values are usually simple numbers (e.g. degrees, m/s). However, numbers can also refer to code values which require lookup in yet another BUFR table to discover the meaning of the number. For example, descriptor 0-01-007 is "Satellite Identifier". A value of 209, say, if looked up in the table for 0-01-007 will translate to "NOAA 18". Flag values are similar, but the number is encoded differently so that several meanings can be incorporated within a single number.

- **END MARKER** (BUFR section 5)

... and that's it

3. Installation and Getting Started

BUFRdisplay is written in Perl and Perl/Tk. However, it is distributed as a self-contained .exe file which includes all the necessary Perl runtime files. You do not therefore need to have Perl installed.

It is released in 32- and 64-bit versions for both Windows and Linux. The Windows releases run under most versions of Windows. The Linux releases were built under Ubuntu 12.04, and may possibly have library incompatibilities if run under different versions of Linux (or their equivalent under other distributions). I am looking into improving its compatibility.

If handling large amounts of data spread across multiple files, it will obviously be better if you use the 64-bit versions.

3.1. Installing

BUFRdisplay isn't installed as such - just unzip the appropriate downloaded file

BUFRdisplay-x64.zip	Windows 64-bit
BUFRdisplay-x64-Linux.zip	Linux 64-bit

to somewhere convenient, say `C:\Program Files\BUFRdisplay` for Windows XP, or `C:\Tools\BUFRdisplay` for Windows Vista & later.

Please note that 32-bit versions are no longer supported, but I may be able to help if you contact me.

3.2. Running

From wherever you unzipped the files, just click on

BUFRdisplay-x64.exe	Windows 64-bit
BUFRdisplay-x64	Linux 64-bit

to run it, or setup a shortcut on your desktop. The first time you run **BUFRdisplay**, it will cache some files which will make it take longer to start - so 30 seconds - so be patient. Thereafter it will start normally.

First of all, a quick run-through to show how BUFR data can be simply displayed.

The following illustrations are taken from a Windows XP display – Linux will appear slightly different.

Having started it, you should then see the screen:

7x BUFRdisplay v0.8.2 180911 64-bit © Francis Breame 2008-2018

File Settings Help

OPTIONS

File filter: Point size: Map x size:
 Map y size:

Display mode
 Point Vector

Decode mode
 Normal Locations HSAF H01/H02 HSAF H08

Vector display
 Use wind symbols Wind symbols colour-coded

Sample rate 1-in-n (HSAF-H08 only):
 Suppress outliers (% of total points):
 Palette:

STATUS

PROGRESS

DECODE PROGRESS

INPUT DATA

Input file: Decode mode:

Total files: Total messages: Total subsets: Av subsets /message: Fields: Total file size kB:
 Data compressed Multiple files BUFR edition Tables version

DATA SELECTION

Select
 Data field
 Vector direction field

Latitude field: 1st value: Longitude field: 1st value: Data field: 1st value: Vector direction field: 1st value: Timestamp:

MAP PARAMETERS

Projection:
 Latitude limits: Longitude limits:
 Central latitude: Central longitude: Height:
 Centre on data Hires (slower) Show countries
 Zoom: Map thickness: Grid thickness:

ACTIONS

MAP PARAMETER ACTIONS

Loaded:

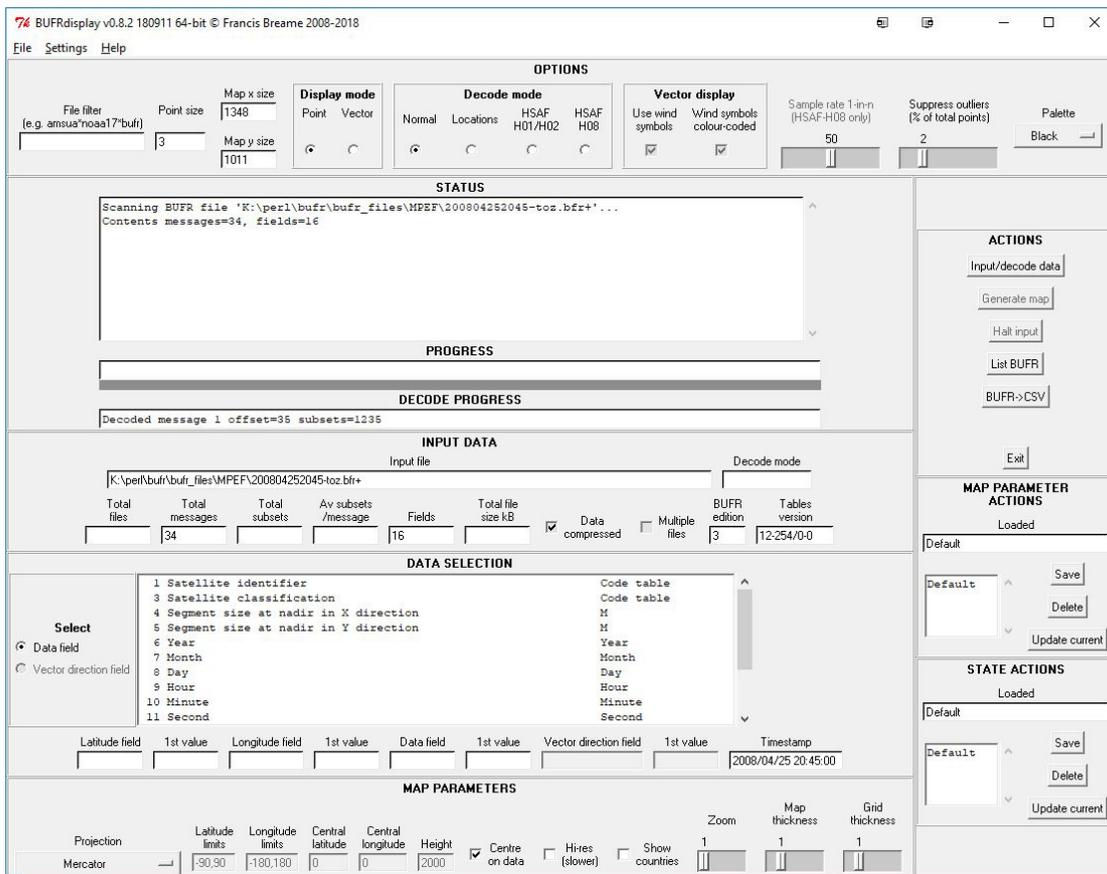
STATE ACTIONS

Loaded:

3.3. Opening A File

Assuming that you have used David Taylor's **MSG Data Manager**, **MetOp Data Manager**, or **AVHRR Manager** to generate the EUMETCast files, use the menu **Files/Open** to select a file in the usual way from wherever those programs left them.

BUFRdisplay will scan the first message in the file and produce, in the **DATA SELECTION** pane, a list of the data fields contained therein. This example doesn't contain many fields - some files contain hundreds.



3.4. Selecting Data

Check that **Data field** under **DATA SELECTION** is selected. Browse through the fields, choose one which looks interesting – in this example, say **Total Ozone** - and click on it. This is field 16, which will appear in the **Data field** box underneath. **Latitude field** (no 12) and **Longitude field** (13) will be automatically selected. (If there are no latitude/longitude fields, then the data is non-geographical and cannot be displayed.)

3.5. Decoding The Data

Now press **Input/decode data** in the **ACTIONS** pane on the right. The file will be decoded (this is not done automatically when the file is opened since some files can contain vast amounts of data).

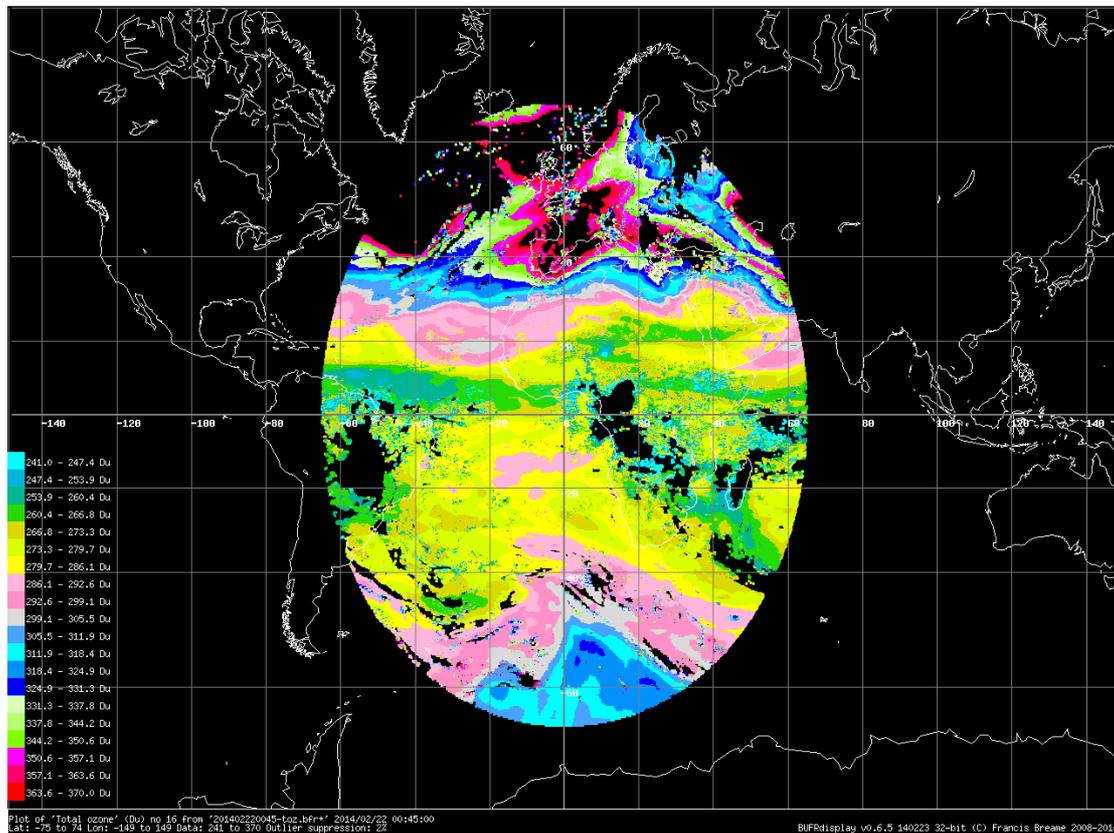
The screenshot shows the BUFRdisplay v0.8.2 software interface. The window title is "BUFRdisplay v0.8.2 180911 64-bit © Francis Breame 2008-2018". The interface is divided into several sections:

- OPTIONS:** Includes fields for File filter (e.g. amsua*noaa17*bufr), Point size (1348), Map x size (1011), Map y size (1011), Display mode (Point/Vector), Decode mode (Normal/Locations/HSAF H01/H02/H08), Vector display (Use wind symbols, Wind symbols colour-coded), Sample rate 1-in-n (50), Suppress outliers (2), and Palette (Black).
- STATUS:** A text area showing the progress of decoding: "Scanning BUFR file 'K:\perl\bufr\bufr_files\MPEF\200804252045-tot.bufr'...", "Contents messages=34, fields=16", "Loading BUFR data from file 1 'K:\perl\bufr\bufr_files\MPEF\200804252045-tot.bufr'...", "Saved data from file 1 in 36809 subsets 34 messages".
- PROGRESS:** A green progress bar indicating the current state of the decoding process.
- DECODE PROGRESS:** A section showing "Decoded message 34 offset=434932 subsets=209".
- INPUT DATA:** A table showing input file details:

Total files	Total messages	Total subsets	Av subsets /message	Fields	Total file size kB	Data compressed	Multiple files	BUFR edition	Tables version
1	34	36809	1083	16	427	<input checked="" type="checkbox"/>	<input type="checkbox"/>	3	12-254/0-0
- DATA SELECTION:** A list of fields to select for display, including "16 Total ozone" which is currently selected. Below the list are fields for Latitude field (12), 1st value (23.46666), Longitude field (13), 1st value (-59.66476), Data field (16), 1st value (243), Vector direction field, and Timestamp (2008/04/25 20:45:00).
- MAP PARAMETERS:** Includes Projection (Mercator), Latitude limits (-90,90), Longitude limits (-180,180), Central latitude (0), Central longitude (0), Height (2000), Centre on data (checked), Hires (slower) (unchecked), Show countries (unchecked), Zoom (1), Map thickness (1), and Grid thickness (1).
- ACTIONS:** A vertical list of buttons: "Input/decode data", "Generate map", "Halt input", "List BUFR", "BUFR->CSV", and "Exit".
- MAP PARAMETER ACTIONS:** Two sections for "Default" settings with "Save", "Delete", and "Update current" buttons.
- STATE ACTIONS:** A section for "Default" settings with "Save", "Delete", and "Update current" buttons.

3.6. Plotting The Data On A Map

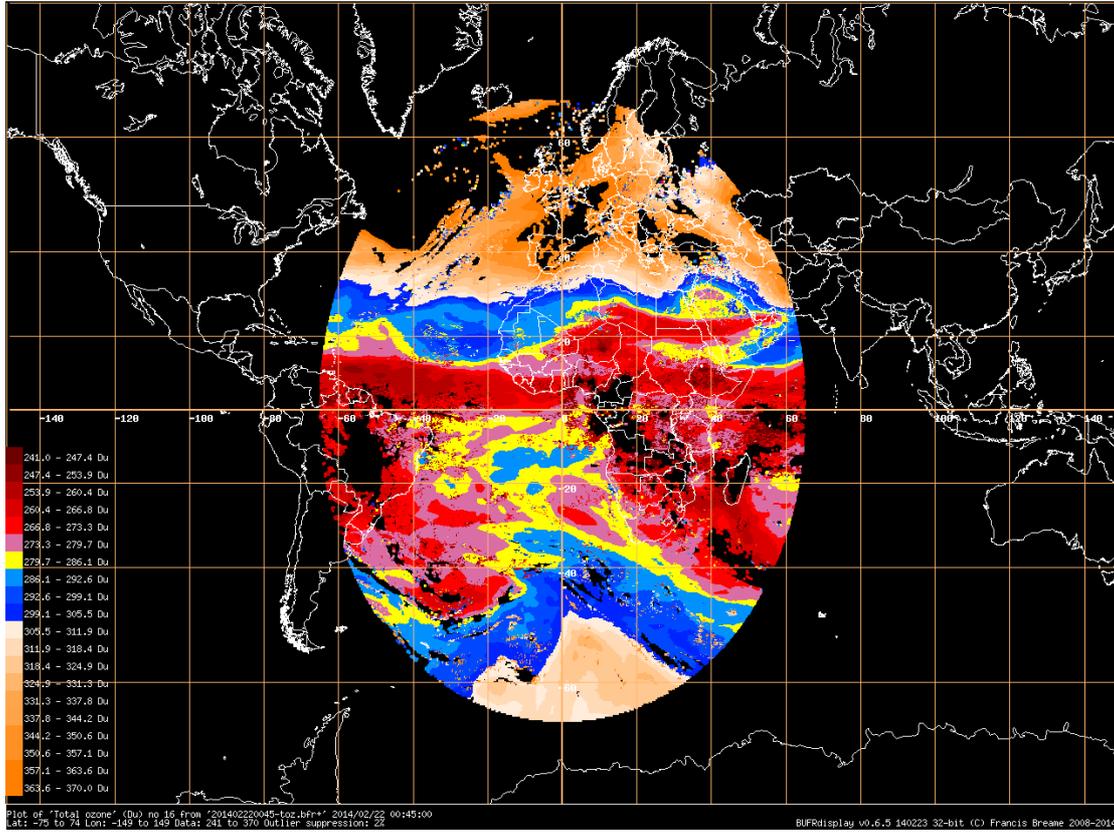
Now press **Generate map** and you should see something like the following, the value ranges being colour coded.



Once you've input the data, you can make different data selections and generate new maps.

If a map seems particularly interesting, use the **File/Save map** menu item to save it as a GIF file.

For a different view, change the **Palette** in the **OPTIONS** pane to **MPEF GII**, and tick **Show countries** and **Hi-res** in the **MAP PARAMETERS** pane. Then press **Generate map** again to produce the following:



4. A Detailed Look

4.1. Menus

First of all, the menus. There are actually very few items:

File

Open	Bring up the usual file chooser and select a file to open. See Section 4.2.2 for multiple file selection.
Save map as...	If data has been plotted on a map, save the map as a GIF file.
Exit	I wonder...

Settings

Palette	Allows creation or editing of the map display palette. See Section 5.
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Help

About	List version information. For actual usage help, you'll have to look at the file you're currently reading.
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4.2. Files

4.2.1. Types

BUFR files do not generally have a standard extension indicating that they are BUFR data. If in doubt, try opening one. You will soon be told if it isn't BUFR.

Some BUFR files which have been compressed with gzip and have a `.gz` extension. (Why? BUFR data is usually compressed internally anyway.) `BUFRdisplay` will uncompress these automatically.

4.2.2. Multiple files

A lot of data is distributed across several files, each contributing to a world view. When opening a file it is therefore possible to select several files in the usual way, either by holding down **CONTROL** while clicking on them individually, or by holding down **SHIFT** and clicking on the first and last of a range. They will then be processed as if they were one. Beware though that this can produce a lot of data which may therefore take some time to decode. The files must obviously all be of the same type.

The maximum number of files you can select simultaneously is dependent on the aggregate length of the file names, but typically might be in the range 500-600 (make sure they are small ones if using this many!). However, an error message will be generated if you exceed the limit (in earlier versions, it appeared that nothing was selected without any warning. If you really need a higher limit, use the `-o` command line option (see Section 8).

4.3. Main Window

The main window of **BUFRdisplay** is divided into a number of logical areas, or panes.

4.3.1. OPTIONS Pane

Starting at the top, we have the **OPTIONS** pane. Miscellaneous options, not surprisingly, may be monitored or changed here.

OPTIONS

File filter
(e.g. amsua*noaa17*buf)

Point size 3

Map x size 1348

Map y size 1011

Display mode
Point Vector

Decode mode
Normal Locations HSAF H01/H02 HSAF H08

Vector display
Use wind symbols Wind symbols colour-coded

Sample rate 1-in-n (HSAF-H08 only) 50

Suppress outliers (% of total points) 2

Palette Black

File filter

Input a name filter specification to restrict the files displayed when opening them using the menu **File / Open**. A * is the wild card. Remember to put * at the beginning unless you want the filename to start with your filter.

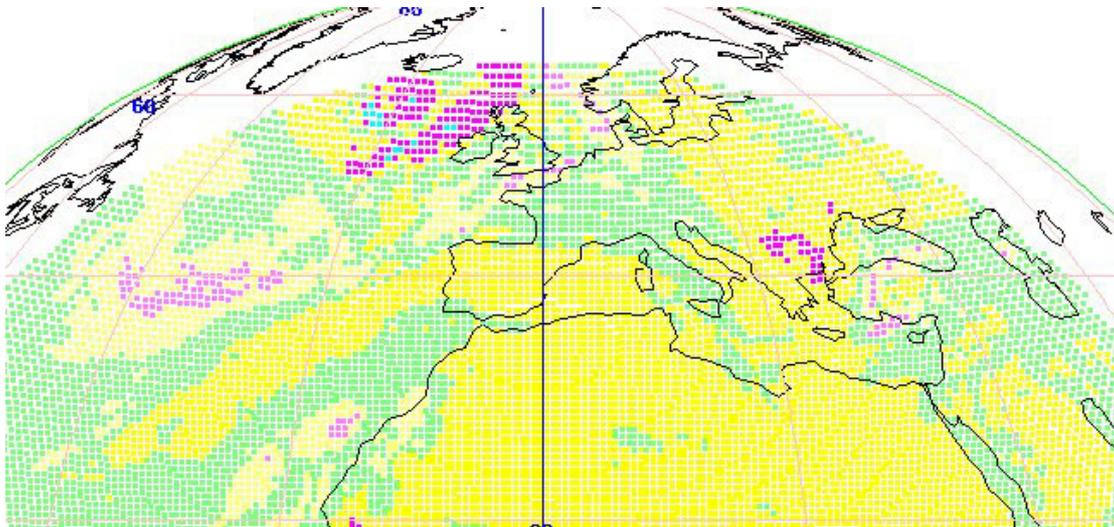
Map x size, Map y size

These are the size of the plotted maps, in pixels. By default, there are generated from the user's screen size (whilst preserving the map's aspect ratio).

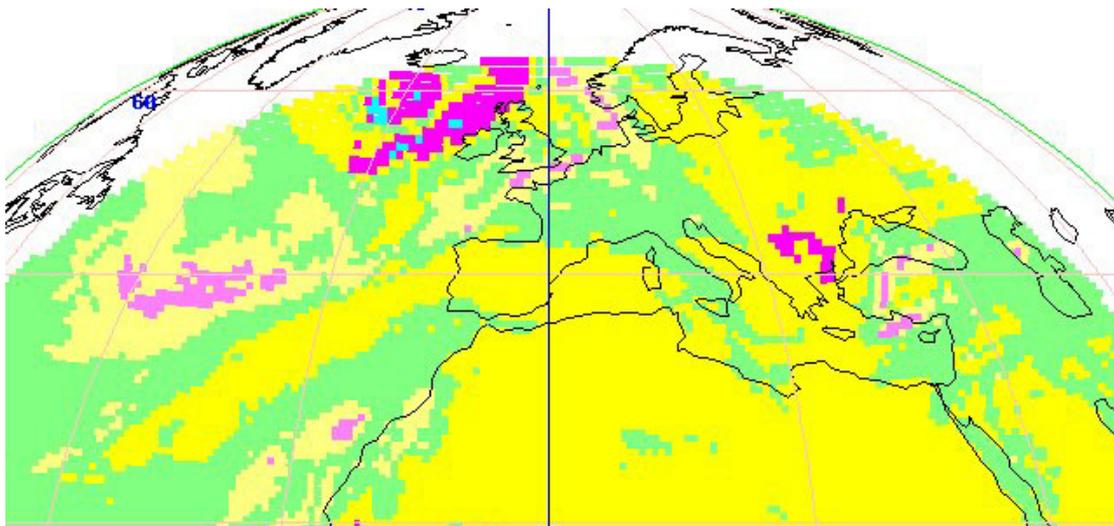
Point size

This is the size of a data point when plotted on the map, as a square with size of this number of pixels. It can be changed by typing in a new value, which may be useful when the data points are rather scattered, allowing them to join up, albeit at a lower resolution, as shown below.

Point size 3 (default)



Point size 5



Display mode

- **Normal**

Just plots the data points on the map, with colours representing bands of values.

- **Vector**

Some data, notably winds, can be displayed as a vector, i.e. consists of two data fields providing both a value and a direction. If **vector** is selected, a direction field can be chosen along with the normal data field (see Section 4.3.4 on how to do this).

Note that, if **templates** are in use (see Section 4.3.4), then vector mode will be chosen automatically, along with the correct direction field.

Vector displays can be altered by selections in the **Vector display** box (see below).

The points can be displayed in two ways:

- A simple arrow pointing towards the direction value, with the data value colour-coded as for other points.
- Standard wind symbols, which is chosen by ticking **Use wind symbols** in the **Vector display** box.

They will be displayed as a single colour as defined in the palette (see Section 5), unless **Wind symbols colour-coded** in the **Vector display** box is ticked. In this case the data value will be colour-coded into bands as for other points.

(I think I have the wind symbols right, but I'm open to correction not being a meteorologist.)

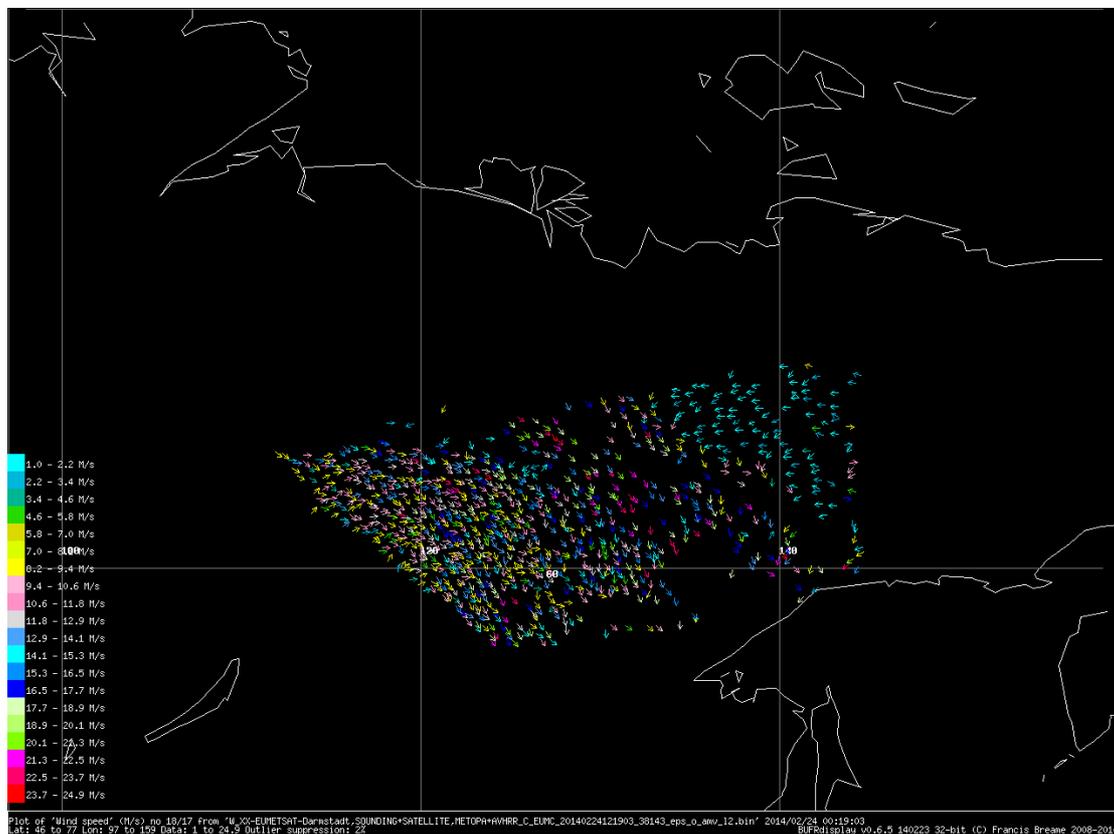
The direction of either symbol will be corrected for the map projection so that it is relative to north on the map.

Good examples are the Polar Winds files from METOP, which have names like

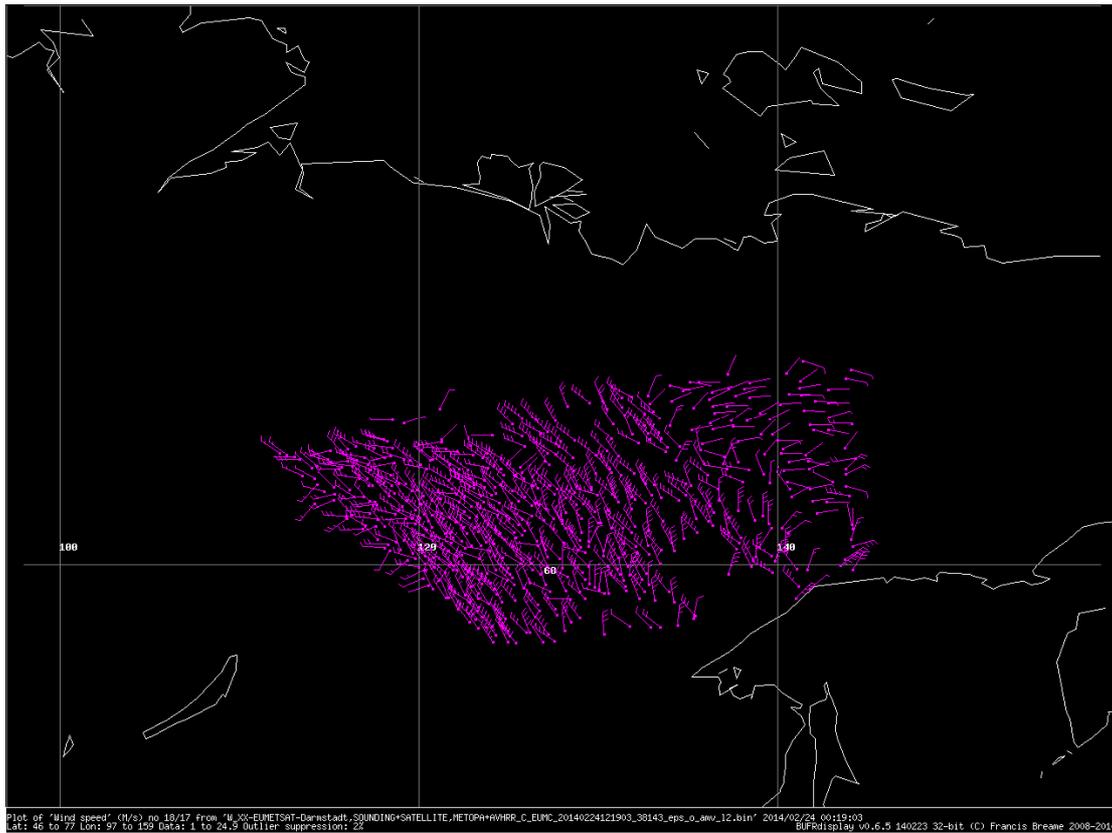
```
W_XX-EUMETSAT-  
Darmstadt,SOUNDING+SATELLITE,METOPA+AVHRR_C_EUMC_20140224121903_38  
143_eps_o_amv_l2.bin
```

Inputting one of these will give you:

Standard vectors



Wind symbols



Decode mode

This selection allows some special post-processing to take place after a BUFR file has been decoded.

There are currently 3 options:

- **Normal**

No post-processing takes place.

- **Locations**

Allows files which consist of just location data (effectively maps) to be displayed. At the moment, I am not aware of any EUMETCast files which contain this type of data.

- **HSAF H01/H02**

Displays EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF):

- Type H01 - Precipitation rate at ground level by MW conical scanners (with indication of phase).
- Type H02 - Precipitation rate at ground level by MW cross-track scanners (with indication of phase).

These files contain line scan data, and thus a given data field (each pixel on the line) must be automatically selected multiple times to complete the line.

To use it, select the first data field in which you are interested

e.g. Intensity of precipitation (high accuracy)

Note that this **must** be preceded a latitude/longitude pair - sometimes a field with the same name will occur at the start of the list, but is not preceded by a location. Selecting this will give "No latitude/longitude found" errors. BUFRdisplay will then select **all** fields in the file with the same name, and display those.

See [7] for more details.

- **HSAF H08**

Displays EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF):

- Type H08 - Small scale surface soil moisture by radar scatterometer).

These files contain very dense data, so make use of the sampling facility (see below). Because of this, data input/decoding may be a little slow.

See [7] for more details.

Beware that, if you use one of these special decode modes on a file which does not contain the correct data, it may well cause **BUFRdisplay** to display meaningless results and/or errors. If in doubt, have a look at the file in **Normal** mode first. I hope to make the program more forgiving later.

It is possible that other decode modes could be added to allow specialised BUFR files to be displayed. Let me know if you have any which might fall under this category (the post-processing cannot be too complex, so it may not be possible).

Vector display

Covered above under **Display mode** type **vector**.

Sample rate 1-in-n (HSAF only)

Samples the input data, whereby only 1 in n data points is used, in support of large datasets.

So far, it only operates with the **H-SAF H08** decode mode, as these files have very dense data. The default is 1 in 50, but may be changed to anywhere from 1 to 100. I suggest that you try the default, but experiment to see what the output resolution looks like.

Suppress outliers (% of total points)

Some files have a few data points with extreme values compared to the bulk of the data ('outliers'). *S-O3M_GOME_O3-NO2-SO2_L2** files are a good example. Since the map display allocates colours linearly spread in bands across the entire range of data values, this means that the bulk of the values will be allocated to a small range of colours in the middle, and thus not be very visible.

Outlier suppression removes data points at the ends (either low or high) of the range of values if there are only a small number of points. Thus the bulk values are better spread out. Points are removed if their number is less than a small percentage of the total number of data

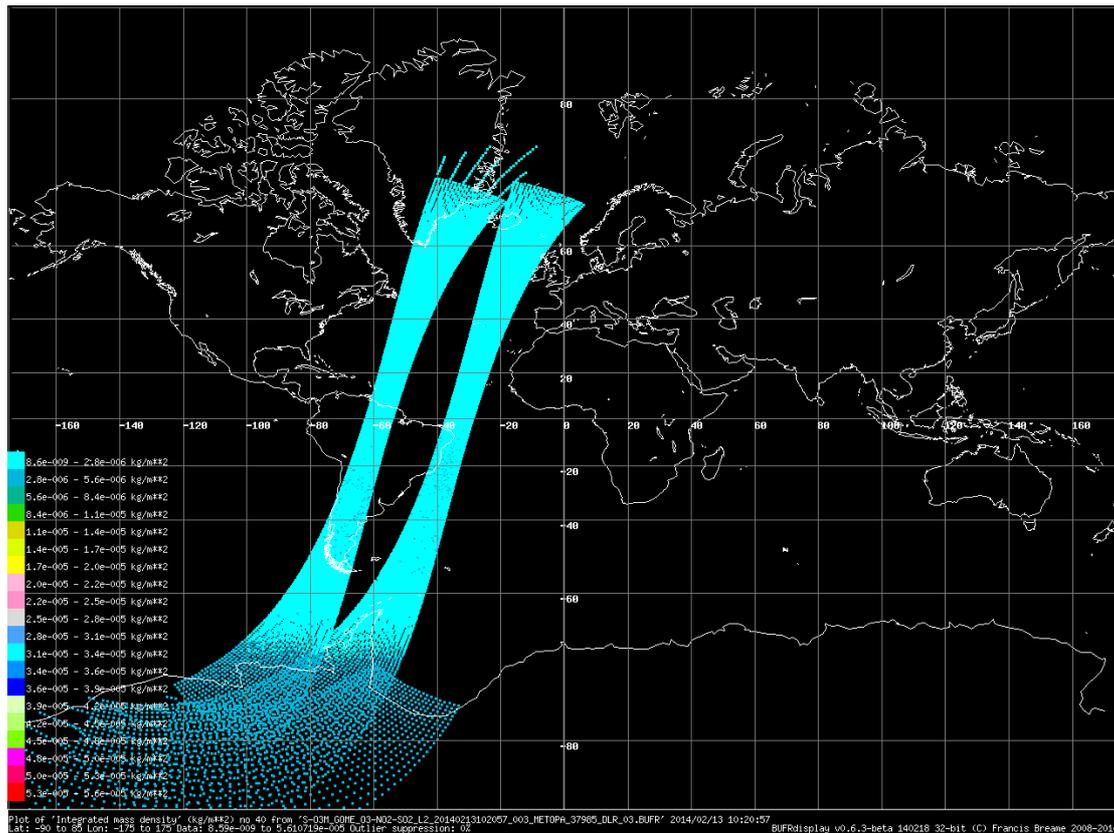
points. The percentage can be adjusted between 0% (meaning that no outliers are removed), and 10%. The default setting is 2%.

Simplified example:

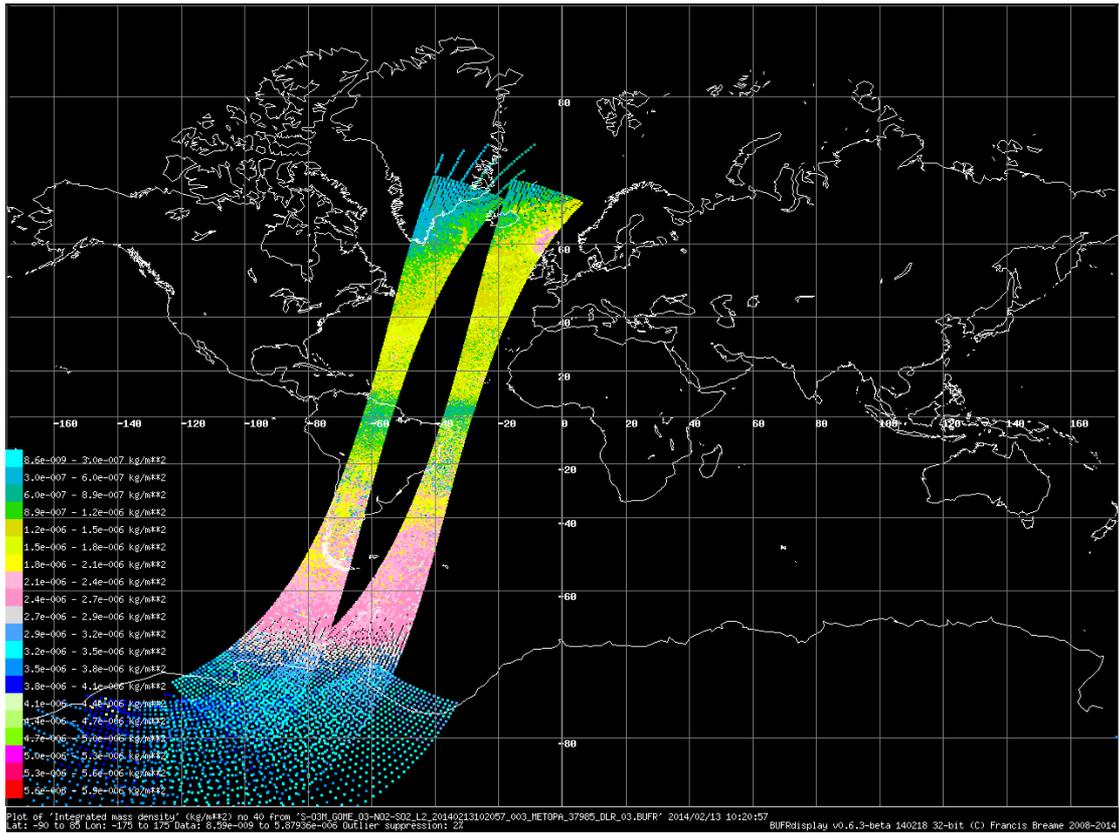
Value band or colour	No of points	Suppressed
0-2	2	*
2-4	1	*
4-6	25	
6-8	20	
8-10	15	
10-12	0	
12-14	10	
14-16	2	*
16-18	0	*
19-20	1	*
Total	76	

Thus the marked bands will be suppressed (each being <2% of 76), and the remaining points reallocated across the range 4-14 (in reality there are 20 value bands or colours).

The following shows a map with no outlier suppression:



and with 2% outlier suppression:

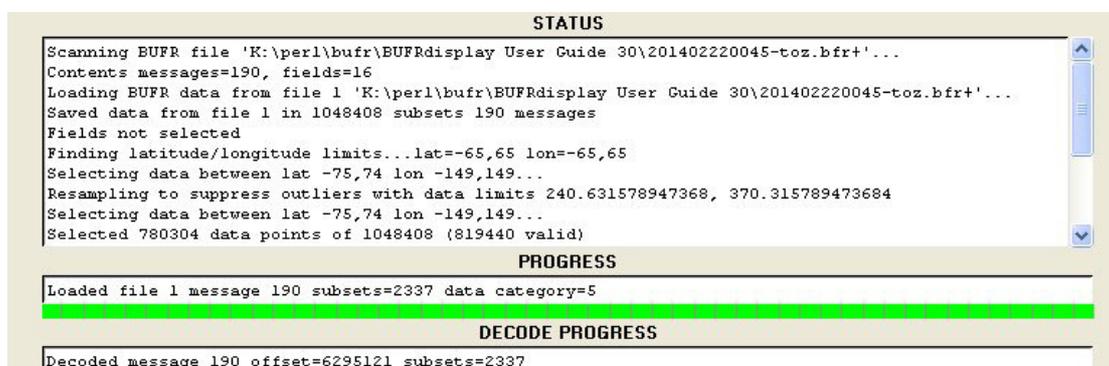


Palette

Chooses the colour palette used when drawing maps – see Section 5.

4.3.2. STATUS Pane

Next comes the **STATUS** pane.



STATUS

```
Scanning BUFR file 'K:\perl\bufr\BUFRdisplay User Guide 30\201402220045-toz.bfr+'...
Contents messages=190, fields=16
Loading BUFR data from file 1 'K:\perl\bufr\BUFRdisplay User Guide 30\201402220045-toz.bfr+'...
Saved data from file 1 in 1048408 subsets 190 messages
Fields not selected
Finding latitude/longitude limits...lat=-65,65 lon=-65,65
Selecting data between lat -75,74 lon -149,149...
Resampling to suppress outliers with data limits 240.631578947368, 370.315789473684
Selecting data between lat -75,74 lon -149,149...
Selected 780304 data points of 1048408 (819440 valid)
```

PROGRESS

Loaded file 1 message 190 subsets=2337 data category=5

DECODE PROGRESS

Decoded message 190 offset=6295121 subsets=2337

Pretty self-explanatory, and shows what **BUFRdisplay** is doing. Any errors encountered will be displayed here.

4.3.3. INPUT DATA Pane

INPUT DATA									
Input file							Decode mode		
K:\perf\bufr\bufr_files\MPEF\200804252045-toz.bfr+							Normal		
Total files	Total messages	Total subsets	Av subsets /message	Fields	Total file size kB	<input checked="" type="checkbox"/> Data compressed	<input type="checkbox"/> Multiple files	BUFR edition	Tables version
1	34	36809	1083	16	427			3	12.254/0-0

The **INPUT** pane simply list information about the input file or files (there can be more than one – see Section 4.2.2). No editing is possible.

Input file

The file currently being processed.

Decode mode

Shows the decode mode used, as selected in the **OPTIONS** pane.

Total files

The number of files input.

Total messages

The number of messages input.

Total subsets

The number of – err, let me see - subsets input.

Av subsets/message

The average number of subsets per message.

Fields

The number of data fields. This must be the same for all files of the same type, otherwise an error will be generated.

Total file size kB

I'll let you guess at this one.

Data compressed

Indicates that the file uses internal BUFR data compression.

Multiple files

Indicates that multiple files have been opened.

BUFR edition

The edition of BUFR which this file uses. The latest is currently 4.

Tables version

The version of the BUFR tables which this file uses. BUFRdisplay chooses the correct ones from this. See section 4.4 for more details if you are really, really interested (probably not).

The format is:

mmm-ccc/sss-lll

where

mmm = Master table version (from WMO)

ccc = Originating centre (as defined in the BUFR code/flags table. 000 if WMO)

sss = Originating subcentre (as defined in the BUFR code/flags table)

lll = Local version (from originating subcentre)

4.3.4. DATA SELECTION Pane

This is probably the most useful pane. It lists all the data fields found in a file, and allows them to be chosen in various ways as controlled by the **Select** : buttons on the left

Select: Data field

DATA SELECTION										
Select <input checked="" type="radio"/> Data field <input type="radio"/> Vector direction field	13	Longitude (high accuracy)	Degree							
	14	Satellite instrument used in data processing(6)	Flag table							
	15	Satellite derived wind computation method	Code table							
	16	Pressure	Pa							
	17	Wind direction	Degree true							
	18	Wind speed	M/s							
	19	Satellite channel centre frequency	Hz							
	20	Satellite channel band width	Hz							
	21	Coldest cluster temperature	K							
	22	Height assignment method	Code table							
	Latitude field		1st value	Longitude field	1st value	Data field	1st value	Vector direction field	1st value	Timestamp
	12		55.58573	13	-32.7909	18	2.2			2008/04/25 20:30:00

This allows the data field which is to be plotted to be selected by clicking on it. Its number will appear in the **Data field** box below. At the same time, latitude and longitude fields will be selected automatically, provided that recognisable fields can be found before the data field.

When a field is chosen, the first value related to it (i.e. the value of the first subset if you read Section 2), if there is one, will be placed in the relevant **1st value** box. This allows a simple way of looking at some of the values quickly. If it is a code/flag value (see Section 2), then the translated value will be shown. Because these are usually rather long, the full value can be read by hovering the mouse over the value box, as shown below.

DATA SELECTION										
Select <input type="radio"/> Data field <input checked="" type="radio"/> Vector direction field	13	Longitude (high accuracy)	Degree							
	14	Satellite instrument used in data processing(6)	Flag table							
	15	Satellite derived wind computation method	Code table							
	16	Pressure	Pa							
	17	Wind direction	Degree true							
	18	Wind speed	M/s							
	19	Satellite channel centre frequency	Hz							
	20	Satellite channel band width	Hz							
	21	Coldest cluster temperature	K							
	22	Height assignment method	Code table							
	Latitude field		1st value	Longitude field	1st value	Data field	1st value	Vector direction field	1st value	Timestamp
	12		55.58573	13	-32.7909	15	Wind derived			2008/04/25 20:30:00
MAP PARAMETER Wind derived from cloud motion observed in the visible channel										

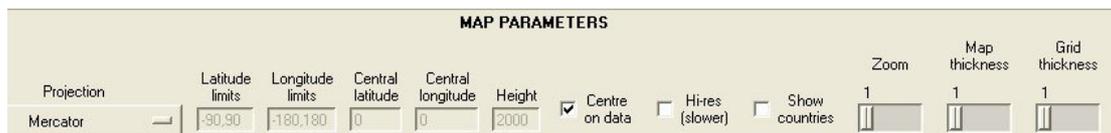
Select: Vector direction field

DATA SELECTION										
Select <input type="radio"/> Data field <input checked="" type="radio"/> Vector direction field	13	Longitude (high accuracy)	Degree							
	14	Satellite instrument used in data processing(6)	Flag table							
	15	Satellite derived wind computation method	Code table							
	16	Pressure	Pa							
	17	Wind direction	Degree true							
	18	Wind speed	M/s							
	19	Satellite channel centre frequency	Hz							
	20	Satellite channel band width	Hz							
	21	Coldest cluster temperature	K							
	22	Height assignment method	Code table							
	Latitude field		1st value	Longitude field	1st value	Data field	1st value	Vector direction field	1st value	Timestamp
	12		55.58573	13	-32.7909	17	204	17	204	2008/04/25 20:30:00

This allows the field containing - yes, you guessed - the direction of a vector to be chosen. It is only enabled if **Vector** is selected in the **OPTIONS / Display mode** box (see Section 4.3.1 for information on displaying vectors).

4.3.5. MAP PARAMETERS Pane

Different maps can be generated by changing settings in the **MAP PARAMETERS** pane.



Projection

Data can be displayed in a variety of map projections - probably far more than are actually useful, but I like playing with them. The following are available at the moment:

- Mercator (default)
- Sinusoidal
- Hammer
- Orthographic
- Perspective
- Stereographic
- Azimuthal equidistant

The two which are handiest are **Mercator**, which is self-explanatory, and **Orthographic**, which produces a view of the earth as seen from infinity, and is particularly useful for polar views. Have a play and see what the results are.

The following settings manually change the view under the selected projection. Not all apply to all projections, and will be greyed out if not applicable. In summary

Projection	Latitude limits	Longitude limits	Central lat	Central long	Height
Mercator	Y	Y			
Sinusoidal	Y	Y			
Hammer	Y	Y			
Orthographic			Y	Y	
Perspective			Y	Y	Y
Stereographic			Y	Y	
Azimuthal equidistant			Y	Y	

By default, the data itself in the file will automatically select the settings so that it is displayed to the best advantage. Thus the manual settings will only be enabled if you untick **Centre on data**.

Latitude limits & Longitude limits

Latitudes are entered between **-90** (south) and **90** (north), and longitudes are entered between **-180** (west) and **180** (east). Limits are entered separated by a comma, e.g.

-120, 120. If necessary, manually entered values will be automatically adjusted to preserve the aspect ratio of the map, so don't be surprised if they change a bit.

If you input a blank, defaults will be used. If you just input a single number in a range, it will be treated as a +/- range, e.g. 20 becomes -20, 20. Any mistakes, e.g. values too big or non-numeric, will be pointed out in the **STATUS** pane and defaults used instead.

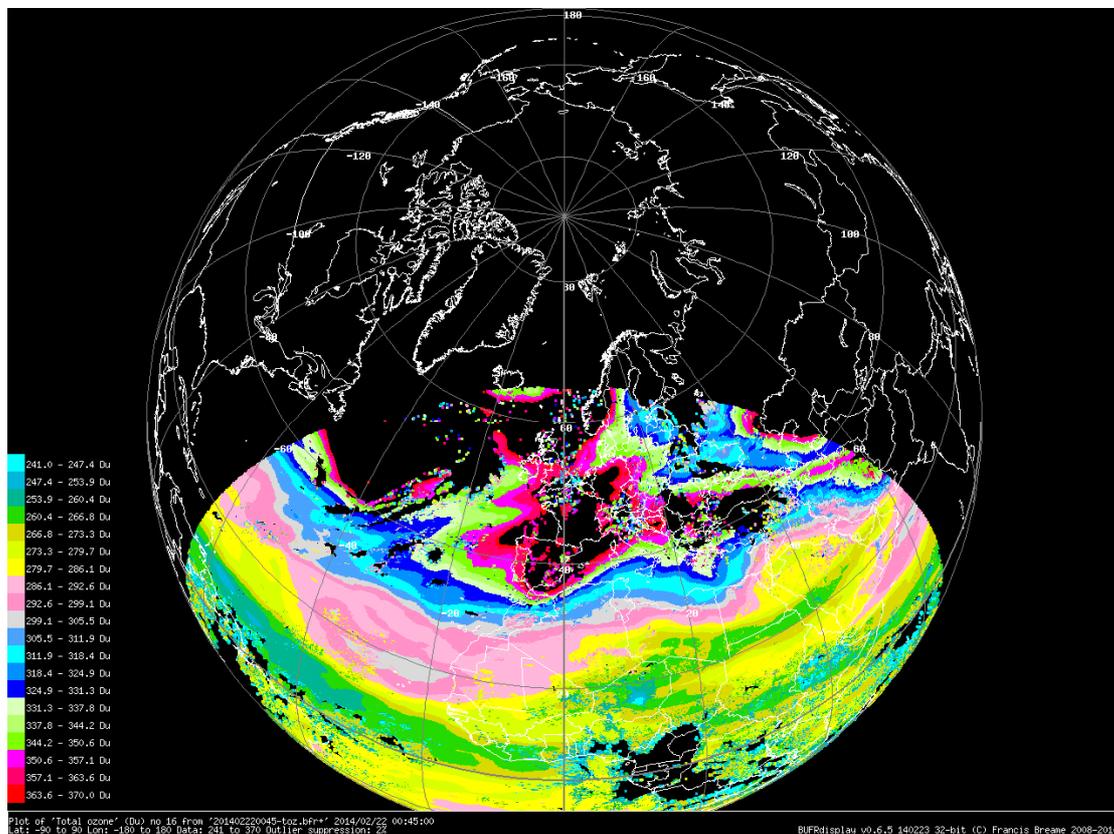
Central latitude & Central longitude

Entered as for limits, except that only a single number is used (obviously).

Height

Used for the Perspective projection only and gives the height of the virtual observer in km. (Orthographic is the same but for an observer at infinity.)

For example, **Orthographic** with **Central latitude=60** gives a view over the north pole:



Centre on data

Disables the manual map settings, and uses the data itself in the file to select them automatically so that it is displayed to the best advantage.

Hi-res

Use a higher resolution map. Don't use unless you need to since it takes longer to draw.

Show countries

Include country boundaries on the map.

Zoom

For non-azimuthal projections (Mercator, Sinusoidal, and Hammer), the latitude and longitude boundaries can be set, thereby selecting part of a map. This is not possible with azimuthal projections (Orthographic, Perspective, Stereographic, and Azimuthal equidistant), where only the latitude and longitude of the map centre can be set. However, by setting **Zoom** to greater than 1, you can draw a map larger than the screen, which can then be scrolled. This is mostly useful for the azimuthal projections, but can be used for all. If the setting is too high, the program may run out of memory.

Map thickness

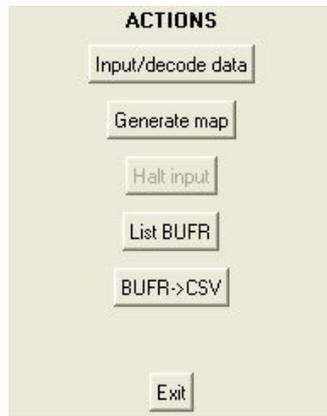
Sets the thickness of the map lines. A higher setting may improve clarity in some cases.

Grid thickness

Sets the thickness of the map latitude/longitude grid lines.

4.3.6. ACTIONS Pane

This pane causes **BUFRdisplay** to do something. They will be greyed out if they cannot be used at that time (e.g. you cannot use **Input/decode data** before opening a file, and you cannot use **Generate map** before running **Input/decode data**).



Input/decode data

Causes the file(s) to be read in and decoded.
See section 3.5.

Generate map

Causes the data to be plotted on a map.
See Section 3.6.

Halt input

Terminates input/decoding if it is taking longer than you want to wait, and saves having to kill the whole program. Useful if you have opened multiple files and regret your choice.

Be aware that it is only actioned at the end of the current message within a BUFR file, so wait a second or two if it does not appear to work at once.

List BUFR

Opens a popup window to permit the generation of a text file detailing the structure and contents of the file(s).
See Section 6 for full details.

BUFR->CSV

Opens a popup window to permit the generation of a comma separated variable (CSV) file holding the decoded data from the file(s) for use by other programs.
See Section 7 for full details.

4.3.7. MAP PARAMETER ACTIONS pane

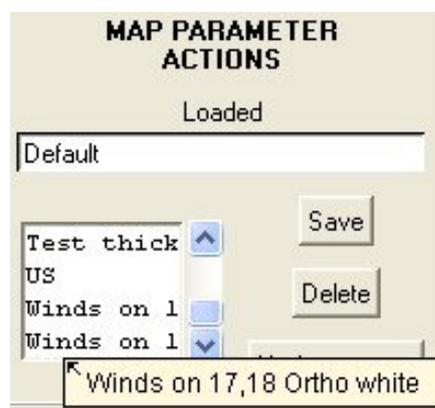
This pane allows you to save and recall a particular set of map settings, so you can easily reload your favourite views.



The following map parameters are saved in each set.

- Map x size
- Map y size
- Projection
- Latitude limits
- Longitude limits
- Central latitude
- Central longitude
- Height
- Centre on data
- Hi-res
- Show countries
- Zoom
- Map thickness
- Grid thickness

The available sets are listed in a selection box. To load one, simply click it. You may want to make the name quite long to act as a description of its contents; however, there is only limited space in the selection box. Therefore if you hover the mouse over a selection box entry, a balloon will pop up showing the full name.



A Default set is always at the top of the list. It is loaded at startup, and cannot be deleted or altered.

To create you own sets, update the actual settings manually just as before on the main panels.

Save

Used once you have established settings you want to keep. You will be asked for a name and the settings will be saved. If the name, which is case-insensitive, already exists, you will be asked if you want to replace it. (Note that, due to the idiosyncrasies of a library used by **BUFRdisplay**, the name cannot contain a dot - you will be prevented from using one which does. Sorry!)

Delete

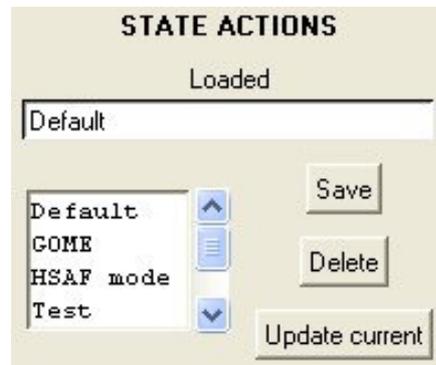
Deletes the selected set following confirmation.

Update current

Simply replaces the currently-loaded set. This lets you easily edit specific settings.

4.3.8. STATE ACTIONS pane

This pane is very similar to the **MAP PARAMETER ACTIONS** pane (Section 4.3.7), but allows you to save and recall nearly all of the **BUFRdisplay** settings (state). It operates in exactly the same way.



You can set up how you wish to view a particular type of file, including the data fields and display mode selected, and save it as a **STATE** set. If you use several data fields from the same file type, then they can be saved in different **STATE** sets. This facility can be used as a more user-friendly substitute for templates (Section 4.3.4). The following settings are saved in each set:

- File filter
- Point size
- Display mode
- Decode mode
- Use wind symbols
- Wind symbols colour coded
- Sample rate
- Outlier suppression %
- Palette
- Name of map parameter set loaded
- Latitude, longitude, and data field numbers
- All map parameters as listed in Section 4.3.7. These override the saved map parameter set – if you alter a map parameter set subsequently, those changes will not be reflected here.

4.4. Table versions

One of the banes of BUFR is the question of table versions, in that each centre/subcentre can produce local versions of the master tables from the WMO, and there is no central registry of them. These local versions can be difficult to get hold of, and in any case require translation to BUFRdisplay's internal format.

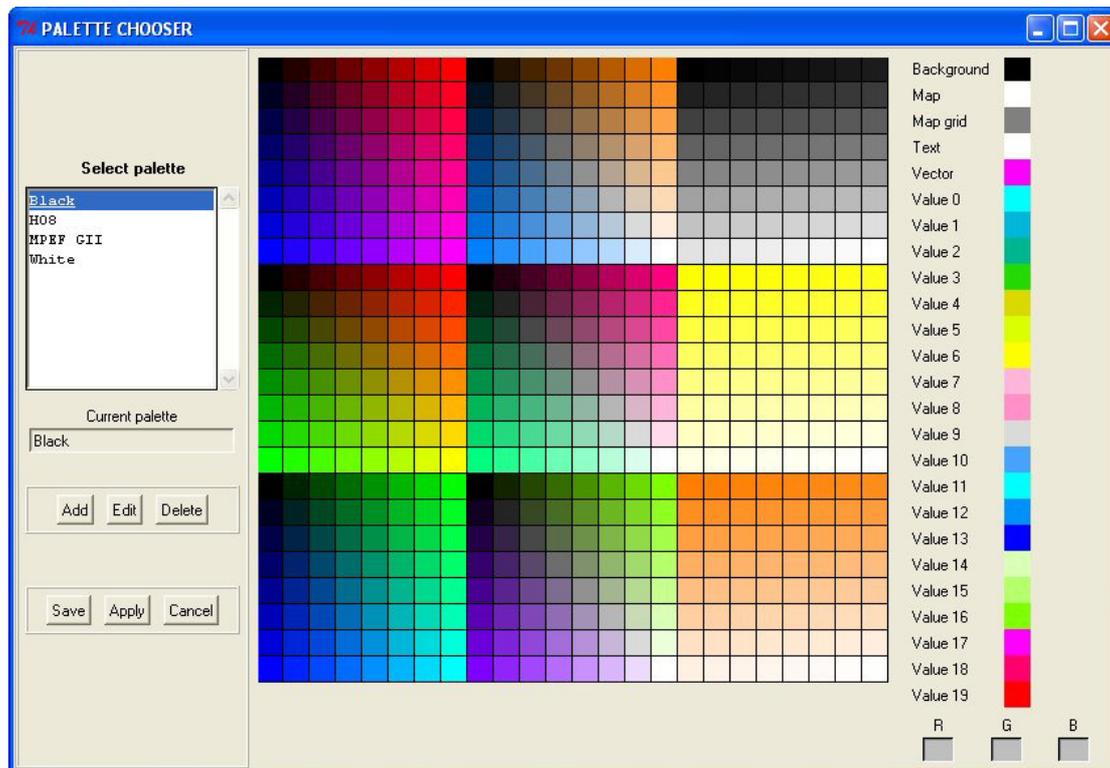
For straightforward data, the local differences are often not significant, so I put an entry in an internal file which tells the program to use an equivalent master version

Because this happens frequently and therefore requires my issuing a new version of the tables each time, BUFRdisplay now does this automatically. If it finds that it need a local table version which does not exist within those supplied with the program, it will automatically use an equivalent WMO master version. There is always the danger that the local alterations will be significant, in which case the decode will fail and the full local version will have to be obtained and input. I therefore output a warning to this effect if it does an automatic equivalence.

5. Palette Editor

The palette editor is invoked by the **Settings/Palette** menu item. I'm sorry about the colour chooser - I wrote it in a hurry. It can probably be improved.

It allows you to edit or create new colour palettes used when drawing maps.



First select the palette you wish to handle. Note that **Black** and **White** are default palettes and cannot be edited or deleted, although they can be viewed. However you can create new versions of them with different names if you wish. The selected palette will appear in the values viewer at the right.

The values viewer gives the values in the palette which are used when drawing maps. The first five are self-explanatory. **Value 0** to **Value 19** are the colours used for plotting data in bands, and are linearly spaced from the data's minimum to maximum value.

R G B shows the red, green, and blue values (from 0 to 255) of a selected colour, either in the value or the colour chooser. When in **Edit** mode, they can also be used for inputting the values directly, rather than using the colour chooser. This can be useful if want to reproduce the RGB values from some other document, having used a graphical editor program to discover them.

The first three buttons change a palette:

Add

You will be asked for a name for a new palette. Once chosen, the name can't be edited, other than by creating a new palette based on it and deleting the old. The initial contents of the new palette will be whatever was in the palette which was selected (if any) before you pressed

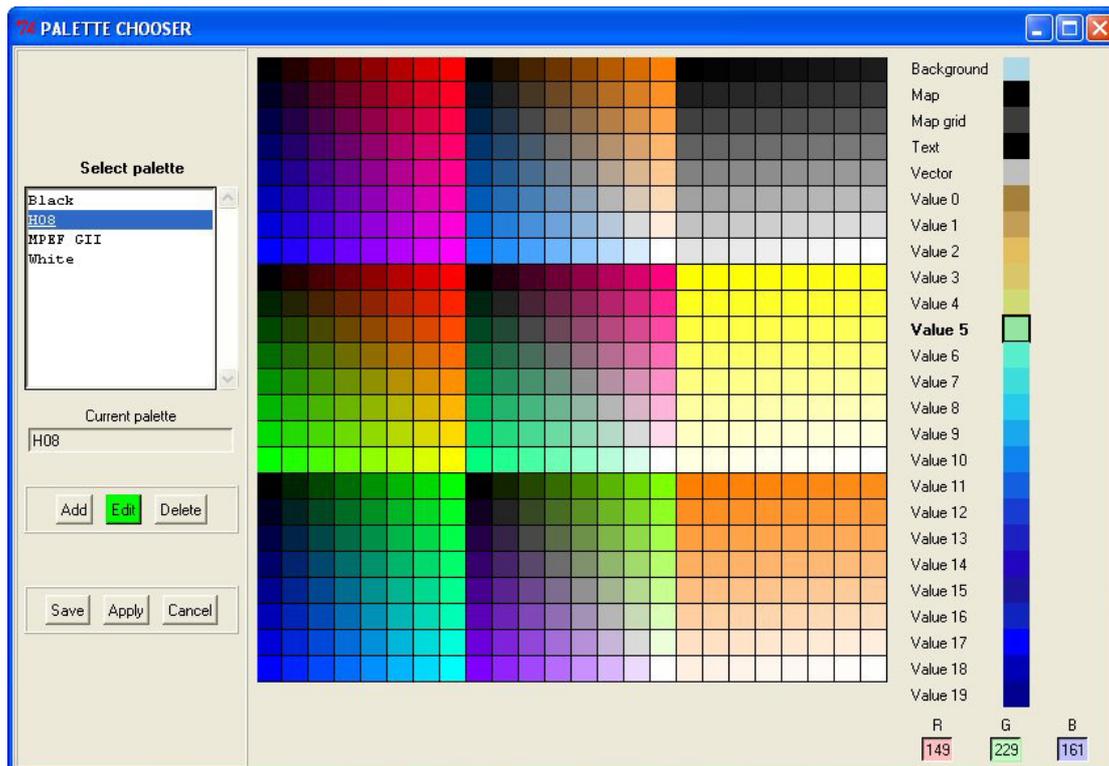
Add - this is a quick way of making a new palette based on an existing one. **Edit** mode is then automatically entered.

Edit

Allows the selected palette to be edited. Once in Edit mode, this button turns green. You can select a field in the value chooser by clicking on it. It will be highlighted as shown below. Change it by clicking on a square in the colour chooser grid in the centre, or by entering the RGB values.

Delete

Deletes the selected palette following confirmation.



The last three buttons close the popup and action the changes you have made. If you don't use **Save** or **Apply**, then you will lose your changes.

Save

Permanently saves the palettes in a file.

Apply

Uses the changes made as long as **BUFRdisplay** is running, but does not save them permanently. Useful if you just want to try something out.

Cancel

Discards any changes you have made.

6. List BUFR Popup

This popup is invoked by the **ACTIONS List BUFR** button. It generates a text file detailing the structure and contents of the file(s). Various options are provided for selecting the amount of detail included.

The screenshot shows a Windows-style dialog box titled "List BUFR". The main area is titled "LIST BUFR FILE CONTENTS". It features an "Input file" field containing a long file path. Below this are two input boxes for "Total files" and "Total messages", and a "Multiple files" checkbox. A "Text output file" field is also present. Under "Include data descriptors:", there are three radio buttons: "None", "Full" (which is selected), and "Descriptive". There are also four checkboxes: "Include data values" (checked), "Include code/flag translation in data values", "Include quality info (debug)", and "Include data descriptor expansion (debug)". At the bottom, there are two dropdown menus for "Subsets to list values for" and "Messages to process", both set to "All". Finally, there are "List BUFR" and "Exit" buttons.

Menu

File

Exit

Quit the popup.

Input file

The file currently being processed if multiple files have been opened.

Total files

The number of files input.

Total messages

The number of messages input.

Multiple files

Indicates that multiple files have been opened.

Text output file

The file selected to save the listing in (see below).

Include data descriptors:

Amount of information to be included about the data descriptors

None

Skip them altogether.

Full

Full information about the data descriptors and their internals

Descriptive

Include just the name and units of the data descriptors.

Include data values

Include the data values in the listing. Which subsets are included may be selected below.

Include code/flag translation in data values

Translate code/flag values to their textual equivalent, rather than just listing the numeric values. Because one line has to be used per value, this option makes the listing longer.

Include quality info (debug)

Have a go at including the quality information, normally ignored. This isn't fully implemented, so is only recommended for debugging.

Include data descriptor expansion (debug)

Trace through the process of expanding the data descriptors. Again, only really of interest for debugging.

Subsets to list values for

If listing data values, specify which subsets are to be included. If blank or "All", then use the lot. Otherwise, a comma-separated list of numbers, which may include ranges as **n-n**, or ***** which represents the maximum subset number, e.g. **1, 3, 6-8, 100-***

Messages to process

Specifies which messages to process. Syntax as for subsets.

List BUFR

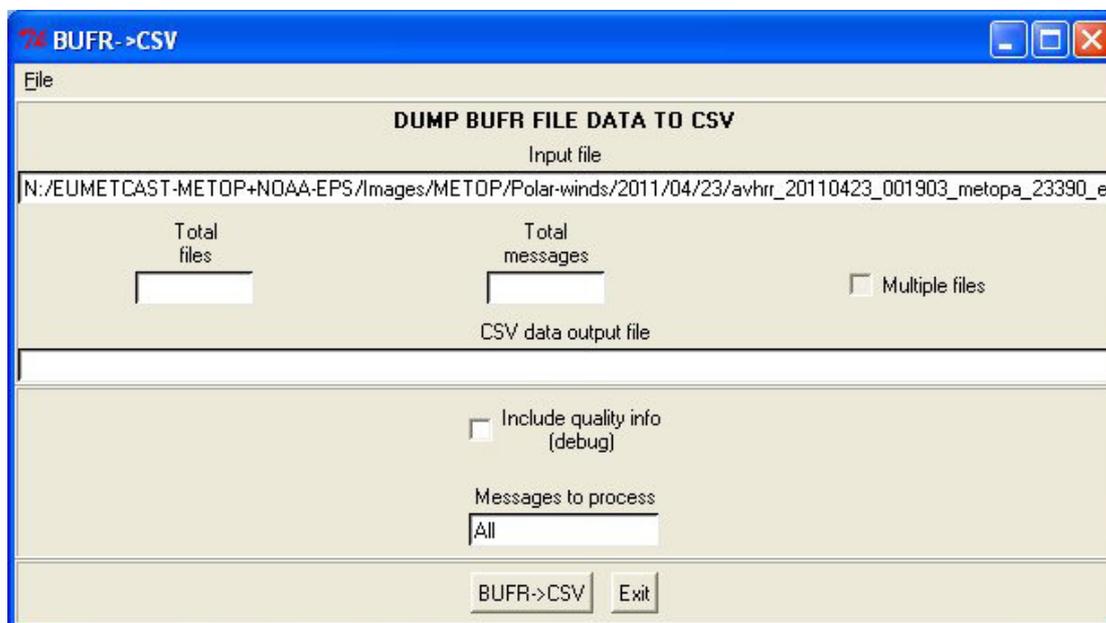
Go do it. A popup will appear for you to choose the output text file.

Exit

Quit the popup.

7. BUFR->CSV Popup

This popup is invoked by the **ACTIONS BUFR->CSV** button. It generates a comma separated variable (CSV) file holding the decoded data from the file(s) for use by other programs.



I also have available a separate program, **BUFRextract** (available on my [www site \[1\]](#)), which uses the same decode engine to produce the same CSV file, but has a command line interface in place of a GUI. It is therefore more suitable to be called from other programs (and is in fact used for some decoding by David Taylor's **BUFR Viewer**).

BUFRextract's User Guide (on [1]) details the format for the CSV file.

Various options are provided for selecting the amount of detail included.

Menu

File

Exit

Quit the popup.

Input file

The file currently being processed if multiple files have been opened.

Total files

The number of files input.

Total messages

The number of messages input.

Multiple files

Indicates that multiple files have been opened.

CSV data output file

The file selected to save the CSV data in (see below).

Include quality info (debug)

Have a go at including the quality information, normally ignored. This isn't fully implemented, so is only recommended for debugging.

Messages to process

Specifies which messages to process. If blank or "All", then use the lot. Otherwise, a comma-separated list of numbers, which may include ranges as **n-n**, or ***** which represents the maximum message number, e.g. **1, 3, 6-8, 15-***

BUFR->CSV

Go do it. A popup will appear for you to choose the output CSV data file.

Exit

Quit the popup.

8. Command Line Options

When BUFRdisplay.exe is started, it is possible to add options to the command line.

- `-f<size>` Linux font size – not applicable to Windows versions.
- `-o<size>` Multiple file open buffer size – see Section 4.2.2.
- `-d<codes>` Set debug levels. Ask if you really want to know the meanings of the codes.

Note that there is no space between the option and its parameter. So, for example,

```
BUFRdisplay.exe -o40000 -f16
```

9. Caveats

Bear in mind that **BUFRdisplay** is based on my understanding of the BUFR format, which is incomplete and probably wrong in some areas. In particular:

- It handles most of the BUFR files received by EUMETCast (but may need updating to handle new file types). It may well handle other BUFR files, but BUFR includes a lot of cases which are rarely used and which it may not handle properly.
- It can only display data if all subsets (and messages) have the same data format, and will warn if this is not the case. Most uncompressed files have different formats between subsets, and therefore cannot be displayed. However, they can be decoded to a csv file for external processing, or by using my program BUFRextract.

An exception is files which are handled by the special decode modes (see Section 4.3.1), such as HSAF H08. These might not be handled by the normal decode mode because of the above limitation.

- Many BUFR files include information relating to the quality of the data, which is important to professionals but less so to this community. **BUFRdisplay** ignores it.
- The Windows 32-bit executable has always had a **BUFRdisplay** icon associated with it. However, this does not appear to be supported in my current 64-bit build environment - you will just get the generic Perl icon.
- It is under continuous development, so things are apt to change without notice!

10. Legal Stuff

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For details of the GNU General Public License see

<http://perldoc.perl.org/perl/gpl.html>

or write to the Free Software Foundation, Inc., 59 Temple Place - Suite 330, Boston, MA 02111-1307, USA.

11. Appendices

11.1. Typical EUMETCast Files

These are some of the BUFR files broadcast via EUMETCast. Note that this list is rather out-of-date.

Prog = Generated by program:

- 1 - MSG Data Manager
- 2 - METOP Manager
- 3 - AVHRR Manager

Prog	Typical file name	S/craft	Contents
2	ASCAT\ascat_20100812_000001_metopa_19780_eps_o_125.l1_bufr	METOP	ASCAT level 1 winds at 12.5 km swath grid
2	ASCAT\ascat_20100812_000003_metopa_19780_eps_o_250.l1_bufr	METOP	ASCAT level 1 winds at 25 km swath grid
2	ASCAT\ascat_20100812_000001_metopa_19780_eps_o_125_ssm.l2_bufr	METOP	ASCAT soil moisture at 12.5 km swath grid
2	ASCAT\ascat_20100812_000003_metopa_19780_eps_o_250_ssm.l2_bufr	METOP	ASCAT soil moisture at 25 km swath grid
1	ATOVS\amsua_20100810_0308_metopa_19753_sva.l1c_bufr	METOP	AMSUA instrument level 1C
1	ATOVS\amsua_20100810_0303_noaa19_07752_lan.l1c_bufr	NOAA	AMSUA instrument level 1C
1	ATOVS\amsua_20100812_000122_noaa19_07777_eps_o.l1_bufr	NOAA	AMSUA instrument GDS level 1
1	ATOVS\amsua_20100810_0540_noaa17_42240_ewa.l1c_bufr	NOAA	AMSUA instrument level 1C
2	ATOVS\atovs_20100812_000017_metopa_19780_eps_o.l2_bufr	METOP	ATOVS Sounding Products
1	ATOVS\hirs_20100810_0527_metopa_19755_mus.l1c_bufr	METOP	HIRS instrument level 1C
1	ATOVS\hirs_20100810_0454_noaa19_07753_mas.l1c_bufr	NOAA	HIRS instrument level 1C
2	ATOVS\hirs_20100812_002455_metopa_19780_eps_o.l1_bufr	METOP	HIRS instrument level 1
2	ATOVS\hirs_20100812_000057_noaa19_07777_eps_o.l1_bufr	NOAA	HIRS instrument level 1
1	ATOVS\mhs_20100810_1027_metopa_19758_lan.l1c_bufr	METOP	MHS instrument level 1C
1	ATOVS\mhs_20100810_0950_noaa19_07755_gil.l1c_bufr	NOAA	MHS instrument level 1C
2	ATOVS\mhs_20100812_000049_metopa_19780_eps_o.l1_bufr	METOP	MHS instrument GDS level 1
2	ATOVS-L2\atovs_20100812_000018_noaa19_07777_eps_o.l2_bufr	NOAA	ATOVS Sounding Products
1	MPEF\201008100000-gii.bfr+	MSG	Global Instability Index
1	MPEF\201008112345-rii.bfr+	MSG	Regional Instability Index
1	MPEF\201008100145-amv.bfr+	MSG	Atmospheric motion vectors
1	MPEF\201008100245-csr.bfr+	MSG	Clear-sky radiances
1	MPEF\201008100245-cla.bfr+	MSG	Cloud analysis
1	MPEF\201008100245-th.bfr+	MSG	Tropospheric humidity
1	MPEF\201008100245-toz.bfr+	MSG	Total ozone
2	Polar winds\avhrr_20100812_080103_metopa_19785_eps_o_amv.l2_bufr	METOP	AVHRR instrument Polar winds
1	SAFIS-O3M_GOME_NOP_02_M02_20100810223259Z_20100810223559Z_N_O_20100811002854Z.bufr	METOP	Near Real Time Ozone Profile
1	SAFIS-O3M_GOME_O3-NO2_L2_20100810053859_003_METOPA_19755_DLR_02.BUFR	METOP	Near Real Time Total Column (O3, NO2, tropospheric NO2)
1	SCAT\ascat_20100810_000601_metopa_19752_eps_o_125_ovw.l2_bufr	METOP	ASCAT level 2 winds at 12.5 km swath grid
1	SCAT\ascat_20100810_000601_metopa_19752_eps_o_250_ovw.l2_bufr	METOP	ASCAT level 2 winds at 25 km swath grid
1	SCAT\scatt_20100810_001057_ers2_00000_ear_o_250_ovw.l2_bufr	ERS-2	SCATT level 2
1	Winds\satwnd.bufrcdf.t.AQUA.D2010222.T0132Z.MCMR.bufr	AQUA	IR cloud-drift polar winds
1	Winds\satwnd.bufrcdf.t.TERRA.D2010222.T0057Z.MCMR.bufr	TERRA	IR cloud-drift polar winds
1	Winds\satwnd.bufrwvap.AQUA.D2010222.T0132Z.MCMR.bufr	AQUA	Water vapour polar winds
1	Winds\satwnd.bufrwvap.TERRA.D2010222.T0057Z.MCMR.bufr	TERRA	Water vapour polar winds

User manuals giving more information about the data are often available from the generating agency's www site, which can usually be traced through the Product Navigator broadcast by EUMETCast or at [6].

11.2. Links and References

- [1] My www site
<http://www.elnath.org.uk/>
- [2] David Taylor's BUFR Viewer program
<http://www.satsignal.eu/software/bufr-viewer.html>
- [3] WMO Documentation, especially 306 Manual On Codes, vol 1.2
<http://www.wmo.int/pages/themes/wmoprod/manuals.html>
- [4] European Centre for Medium-Range Weather Forecasts (ECMWF) - Unix BUFR decoding software
<http://www.ecmwf.int/products/data/software/bufr.html>
- [5] A Guide To The WMO Code Form FM 94 BUFR - very useful if you want to write a decoder
<http://rda.ucar.edu/docs/formats/bufr/bufr.pdf>
- [6] EUMETSAT Product Navigator
<http://www.eumetsat.int/Home/Main/DataProducts/ProductNavigator/index.htm>
- [7] Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF)
<http://hsaf.meteoam.it>