

OBJECTIVES

- Understand WMO binary data formats used in WIS2
- Decode BUFR, and GRIB datasets
- Use ecCodes for decoding
- Explore operational workflows for WIS2 data exchange
- Apply practical decoding techniques in meteorological systems

WHY DECODE WMO BINARY FORMATS?

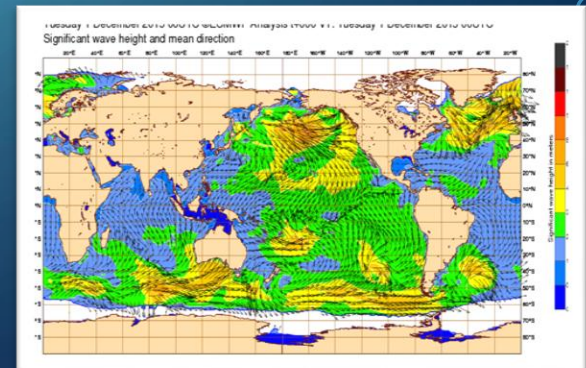
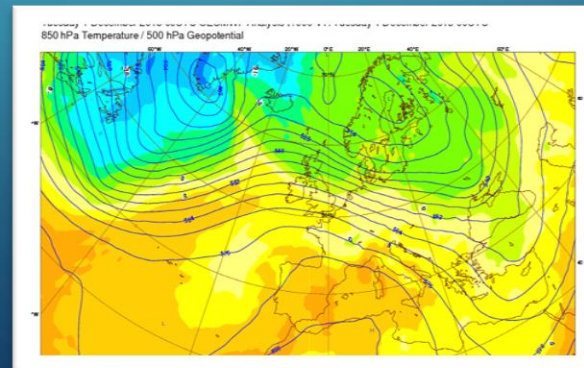
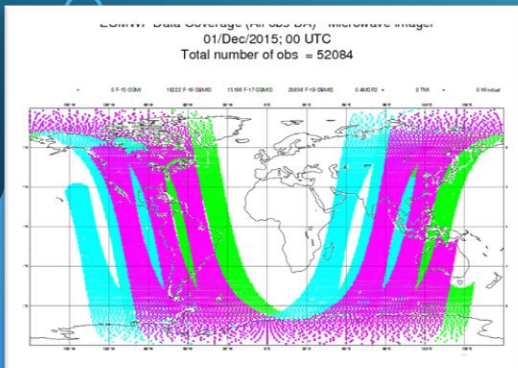
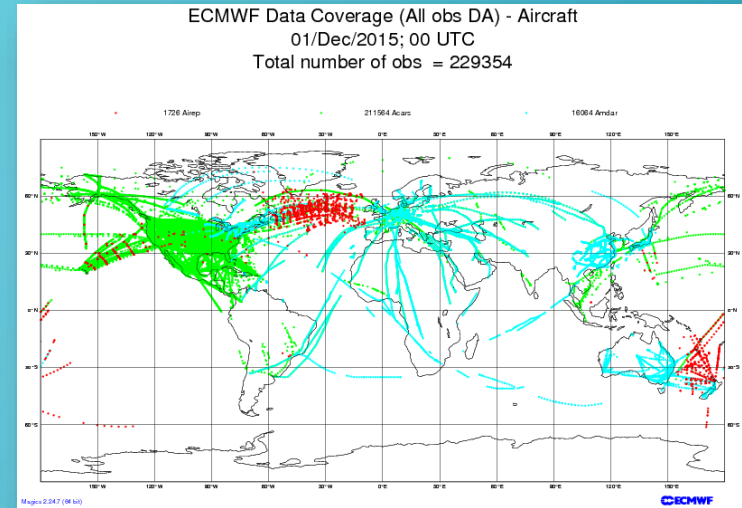
- Meteorological data is distributed in compact binary structures
- Efficient for large datasets and real-time dissemination
- Supports global interoperability across NMHS systems
- Required for forecast models, observations, and climate products

MAIN WMO FORMATS

- BUFR (**B**inary **U**niversal **F**orm for the **R**epresentation of meteorological data)
 - observational data exchange
- GRIB (**G**eneral **R**egularly-distributed **I**nformation in **B**inary form)
 - numerical weather prediction and model grids

BUFR OVERVIEW


- Table-driven binary format
- Widely used for observational data
- Supports synoptic, marine, upper-air, aircraft, and satellite data
- Flexible and extensible through WMO descriptor tables



- BUFR tables for radar are not visual image tables. They are strictly structured text, CSV, or XML catalogs published by the WMO that define the exact meaning, scale, and bit-width of radar data.
- In a radar decoder, BUFR tables are translated into simple text or reference catalogs that link 6-digit descriptors to specific values (e.g., reflectivity, velocity, etc).


Radar BUFR tables are primarily divided into four key components:

- **1. Table B: The Element Descriptor Table**
- Table B defines the physical radar variables and parameters. It uses the format F-XX-YY, where F indicates the type, XX is the data class, and YY is the specific entry.

Descriptor 	Element Name	Unit	Scale	Reference Value	Data Width (bits)
0-21-007	Radar reflectivity factor	dBZ	2	-9000	15
0-21-009	Vertical Doppler velocity	m/s	2	-10000	15
0-02-140	Satellite radar beam azimuth	degree	3	0	16


• 2. Table D: The Sequence Descriptor Table

- Table D acts as a macro. It groups multiple Table B descriptors into organized sequences so encoders don't have to list every single radar variable every time.

Sequence Descriptor 	Contains (Table B Descriptors)	Description
3-01-049	0-01-007 , 0-04-001 to 0-04-005	Radar beam data (Station identification + Time/Date)
3-01-192	0-08-080 , 0-02-198	Sequence for describing geographic projection and x/y offsets

• 3. Code and Flag Tables

- These specify non-continuous, qualitative metadata (such as the operational status of the radar, the scan mode, or clutter treatment)

Code Figure 	Meaning (e.g., Clutter Treatment)
0	No clutter treatment applied
1	Static filter
2	Doppler filtering
31	Missing data

- **4. Table A & Table C**
- **Table A** defines the overall data category (e.g., "Radar data" or "Vertical soundings").
- **Table C** contains operators that allow decoders to modify data width or scale in real-time.

To explore machine-readable or human-readable formats used by meteorological agencies, you can browse the full documentation and templates maintained by the [WMO Manual on Codes](#) or download the European OPERA radar conversion templates on the [EUMETNET OPERA BUFR Guidelines](#)

XML / CSV

```
▼ <stags>
  ▼ <site name="Augusta Treverorum">
    ▼ <gts>
      <header>full</header>
      <trailer>on</trailer>
      <nnn>747</nnn>
      <tt>PA</tt>
      <aa>auto</aa>
      <a2vvp>B</a2vvp>
      <cccc>AUGS</cccc>
    </gts>
    ▼ <gtsoption>
      <type>fixed</type>
      <fixed>80</fixed>
      <coderrange range="50" value="41"/>
      <coderrange range="100" value="42"/>
    </gtsoption>
    ▼ <station>
      <desc f="0" x="1" y="1" value="0"/>
      <desc f="0" x="1" y="2" value="0"/>
      <desc f="0" x="2" y="1" value="2"/>
      <desc f="0" x="2" y="3" value="3"/>
      <desc f="0" x="2" y="101" value="0"/>
      <desc f="0" x="2" y="121" value="5600000000"/>
      <desc f="0" x="7" y="1" value="100"/>
    </station>
  </site>
  ▼ <site name="Minas Tirith">
    <gts/>
    <gtsoption/>
    ▼ <station>
      <desc f="0" x="1" y="1" value="0"/>
    </station>
  </site>
  <site name="Not OK site"/>
  ▼ <site name="Least OK site">
    <station/>
  </site>
</stags>
```

1	BUFR TABLES RELATIVE TO SECTION 3;;;
2	
3	BUFR Table B — Classification of elements;;;
4	
5	F;X;Class;Comments
6	0;0;BUFR table entries;
7	0;1;Identification;Identifies origin and type of data
8	0;2;Instrumentation;Defines instrument types used
9	0;3;Reserved;
10	0;4;Location (time);Defines time and time derivatives
11	0;5;Location (horizontal – 1);Defines geographical position
12	0;6;Location (horizontal – 2);Defines geographical position
13	0;7;Location (vertical);Defines height
14	0;8;Significance qualifiers;Defines special character of data
15	0;9;Reserved;
16	0;10;Vertical elements and pressure;Height
17	0;11;Wind and turbulence;Wind speed
18	0;12;Temperature;
19	0;13;Hydrographic and hydrological elements;Humidity
20	0;14;Radiation and radiance;
21	0;15;Physical/chemical constituents;
22	0;19;Synoptic features;
23	0;20;Observed phenomena;Defines present/past weather
24	0;21 1583 Class 35 - Data monitoring information;;;;;;;;;;
25	0;22 1585
26	0;23 1586
27	0;24 1587 TABLE REFERENCE;;;;;;;;;;
28	0;25 1588 TABLE;;;;;;;;;;
29	0;26 1589 ELEMENT NAME;BUFR;CREX;;;;;;;;;
30	0;27 1590
30	0;27 1591 UNIT;;;;;;;;;;
31	0;28 1592 SCALE;;;;;;;;;;
	1593 REFERENCE VALUE;DATA WIDTH (Bits;;;;;;;;;
	1594 UNIT;;;;;;;;;;
	1595 SCALE;DATA;;;;;;;;;;
	1596 WIDTH;;;;;;;;;;
	1597 (Characters);;;;;;;;;;
	1598 F;X;Y;;;;;;;;;
	1599 0;35;0;FM and regional code number;Code table;0;0;10;Code table;0;3
1600	0;35;1;Time-frame for monitoring;Code table;0;0;3;Code table;0;1
1601	0;35;11;Number of reports actually received;Numeric;0;0;14;Numeric;0;4
1602	0;35;21;Bulletin being monitored (TTAAii);Character;0;0;48;Character;0;6
1603	0;35;22;Bulletin being monitored (YGGgg);Character;0;0;48;Character;0;6
1604	0;35;30;Discrepancies in the availability of expected data;Code table;0;0;4;Code table;0;1
1605	0;35;31;Qualifier on monitoring results;Code table;0;0;7;Code table;0;2
1606	0;35;32;Cause of missing data;Code table;0;0;4;Code table;0;1
1607	0;35;33;Observation and collection deficiencies;Code table;0;0;7;Code table;0;2
1608	0;35;34;Statistical trends for availability of data (during the survey period(s));Code table;0;0;3;Code table;0;1

BUFR MESSAGE SECTIONS

- Section 0 – Indicator Section
- Section 1 – Identification Section
- Section 2 – Optional Section
- Section 3 – Data Description Section
- Section 4 – Data Values
- Section 5 – End Section

recipe

Contains a list of six digit descriptors in the form **F-X-Y** → **0-04-006**

Descriptors starting with

F=0 are elements listed in **Table B**

F=1 denote replication of descriptors

F=2 are operators acting on descriptors

F=3 are sequences of descriptors listed in **Table D**

SECTION 3

```
301051 004006 007002 010004
012001 011001 011002 011031
011032 011033 020041
```

SECTION 4

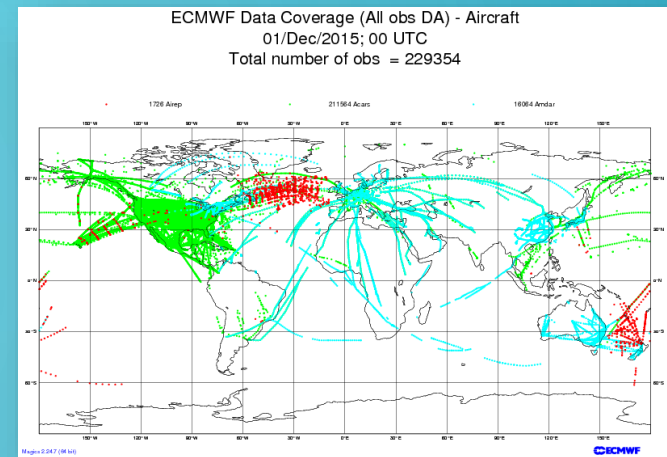
```
010010101110101001010101010
10100010001010101010001010100
10100101010010010100101001010
10101010101111000010101001001
```

Contains the encoded values as a **bit stream** which can be decoded

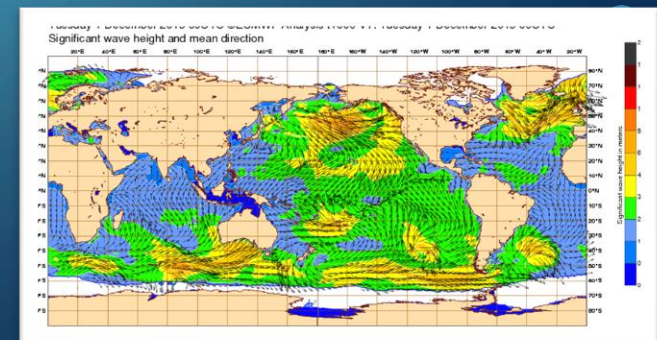
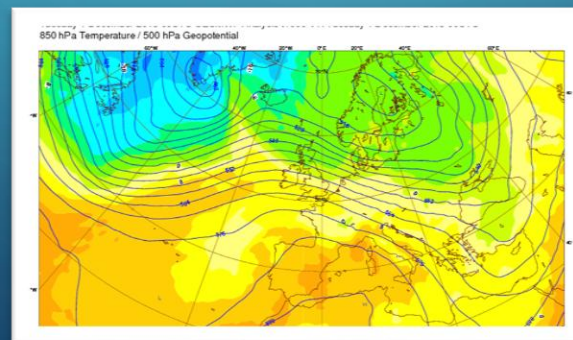
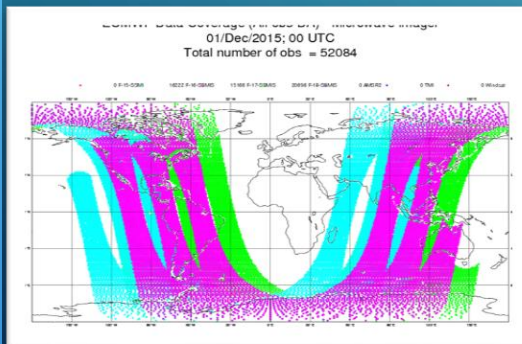
- Implementing the decoding regulations and notes
- Using the Tables

ingredients

GRIB OVERVIEW



- Optimized for gridded meteorological data
- Used in weather forecasting systems worldwide
- Supports forecasts, analyses, and ensemble products
- Compact and efficient storage for large grids



EXAMPLES OF DECODING TOOLS

- **Metview** is primarily a meteorological workstation, visualization, and data-processing tool. It can **read, inspect, decode, filter, and visualize both BUFR and GRIB data**, but it relies on ECMWF's **ecCodes** library to do the actual BUFR/GRIB decoding.
- **AWIPS** (Advanced Weather Interactive Processing System) is a much larger operational forecasting system used by meteorological services. It ingests and decodes many meteorological formats, including **GRIB and BUFR**, as part of its data-processing pipeline. The decoded data are then displayed and analyzed in AWIPS applications.
- ECMWF's **ecCodes** is specifically designed for encoding and decoding WMO GRIB and BUFR formats. If your goal is simply to verify that a BUFR file generated by `wis2box` is valid and contains the expected observations (e.g., SYNOP, TEMP, AWS data), `ecCodes` tools (`bufr_dump`, `bufr_ls`) or Metview are usually the easiest options. AWIPS is generally much heavier to install and operate for that purpose.

ECCODES TOOLS

- Developed by ECMWF
- Decode and encode BUFR and GRIB formats
- Supports command-line and Python APIs
- Common tools: `bufr_dump`, `grib_dump`, `grib_ls`

bufr_dump (JSON or flat dump of the BUFR content)

bufr_filter (a simple filter to modify and print values)

bufr_compare (to compare two BUFR files)

bufr_copy (selective copy of BUFR messages)

bufr_get (get values from a BUFR file)

bufr_set (set values in a BUFR file)

bufr_ls (list the content of the header of BUFR messages in a file)

For your WIS2 work, it may help to think of them this way:

Tool	GRIB	BUFR	Primary Purpose
Metview	Yes	Yes	Inspect, decode, analyze, visualize meteorological data
AWIPS	Yes	Yes	Operational forecasting, data ingest, display, warning generation
ecCodes	Yes	Yes	Core encoding/decoding library used by many applications, including Metview

OPERATIONAL WORKFLOW

- Receive data from WIS2 subscription
- Validate metadata and headers
- Decode binary payload
- Extract meteorological variables
- Store or visualize decoded information

DATA CONVERSION TOOLS

- synop2bufr converts FM-12 SYNOP to BUFR
- csv2bufr converts AWS CSV data into BUFR
- Supports migration from legacy formats
- Integrated into wis2box workflows

The screenshot shows the 'WIS2 in a box' web interface. The main heading is 'Submit FM 12-XIV Ext. SYNOP Bulletin'. Below the heading, there is a link to the WMO Manual on Codes, Volume 1.1. The interface includes a sidebar with navigation options: Home, SYNOP Form, Upload file, Dataset Editor, Stations, and Monitoring. The main content area has a date input field set to '06/2026', a text area for 'Month and year in UTC', a large text input field containing 'FM 12', a 'Raw FM 12 bulletin' section with a 'Dataset Identifier' dropdown menu, and an authentication token field with the value 'wis2box auth token for 'processes/wis2box''. At the bottom, there is a 'SUBMIT' button and a checked checkbox for 'Publish on WIS2'.

```
SMTD31 TTPP 171800
AAXX 17184
45678 11565 71008 10315 20243 30086 40111 69901 78062 83272
333 10322 20245 59019 83820 87360 90914=
```

```
wsi_series,wsi_issuer,wsi_issue_number,wsi_local,wmo_block_number,wmo_station_number,
0,20000,0,78970,,,1,2026,2,12,14,0,17.5349,-88.3128,5.0,6.7,101840,101950,,,1.7,295.1
```

BEST PRACTICES

- Use official WMO and ECMWF tools
- Validate binary messages before processing
- Maintain updated descriptor tables
- Automate decoding pipelines
- Monitor operational WIS2 feeds continuously

SUMMARY

- WMO binary formats are essential for modern meteorological exchange
- BUFR and GRIB are core formats in WIS2
- ecCodes simplifies operational decoding workflows
- Visit WMO site: manuals on codes, libraries, etc

The background is a dark teal gradient. In the corners, there are decorative white line-art elements resembling circuit traces or data paths, with small circles at the end of the lines.

THANK YOU

***PRACTICAL SESSION STARTS
NOW:
EXAMPLE DECODING AND
VISUALIZING DATA USING
OPEN-SOURCE TOOLS***