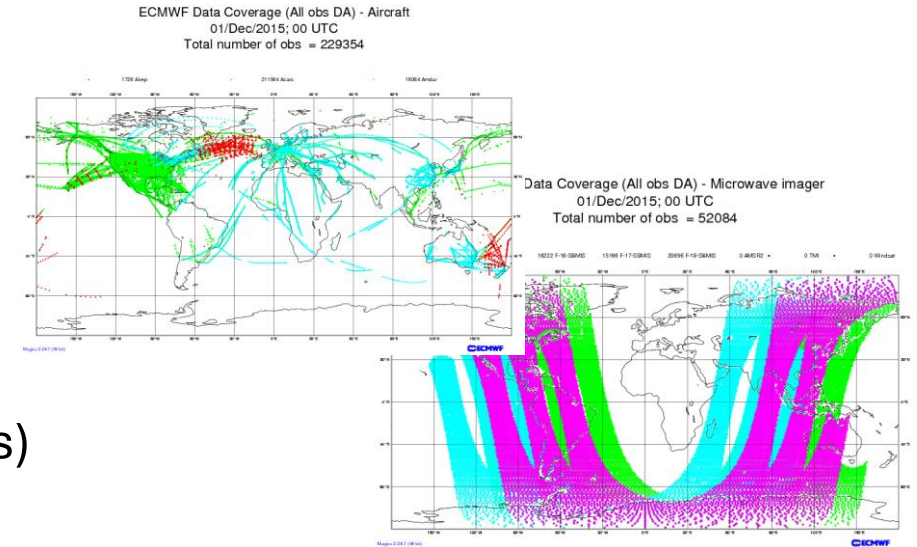


WMO Binary Codes and data conversion tools in the wis2box

WMO Binary codes

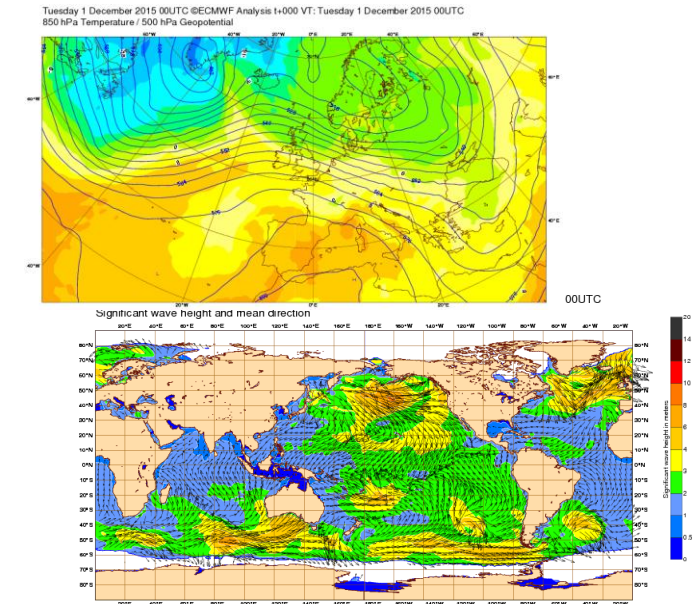
BUFR (Binary Universal Form for the Representation of meteorological data)

- a flexible binary format
- mainly used to encode **in situ and satellite observations**
- can also represent forecast data (e.g. tropical cyclone tracks)



GRIB (General Regularly-distributed Information in Binary form)

- designed to encode data produced by **numerical weather prediction** models.
- can also represent observations, but on a regularly distributed coverage



WMO Binary Codes: BUFR

How BUFR Works:

- **BUFR message** consists of a **header** and a **body containing data and metadata**.
- **BUFR descriptors** define how data is structured and encoded within a BUFR message
- **Compression for efficient storage** to reduce transmission times.

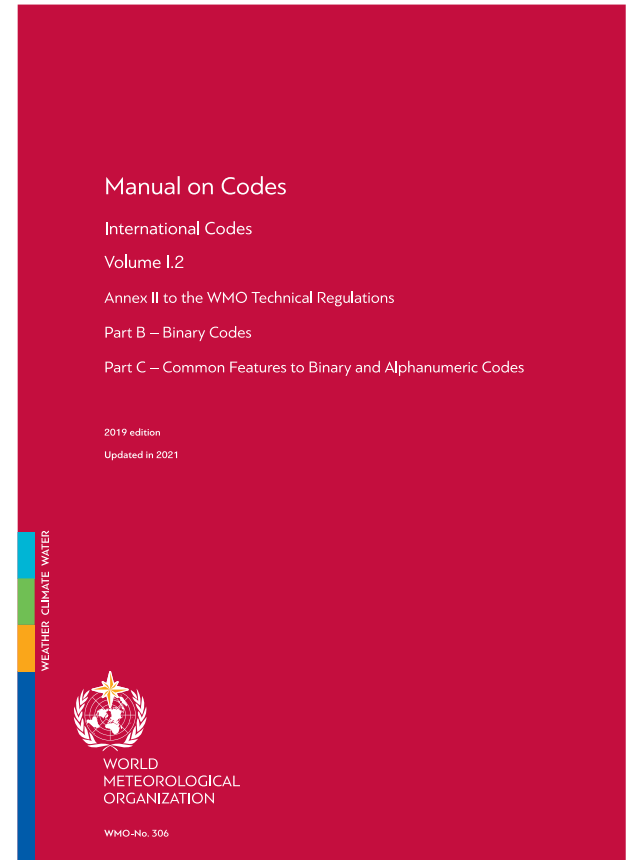
BUFR Table System

BUFR descriptors are stored in **BUFR Tables** (Tables A, B, C, and D).

- **Table B** contains all **element** **descriptors** with their definitions.
- **Table D** defines **combinations of descriptors** into predefined **sequences**

BUFR tables are part of the **WMO Manual on Codes**:

<https://library.wmo.int/idurl/4/35625> new version is released **every six months**



recipe

SECTION 3

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

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 4

```
010010101110101001010101010
101000100010101010001010100
101001010100100101001001010
01010101111000010101001001
```

ingredients

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

- Implementing the decoding regulations and notes
- Using the Tables

WMO Binary codes

42	55	46	52	00	00	DC	03	00	00	12	00	00	62	01	80	00	01	0D	01	0C	0A
1E	00	00	00	00	00	34	00	01	01	7D	CA	78	00	00	7E	95	46	00	4A	59	34
00	39	31	33	33	34	20	20	20	20	20	20	20	20	20	20	20	20	00	DC	78	05
26	78	03	08	02	00	00	00	46	00	00	00	00	00	1C	00	00	01	80	C7	05	0D
17	0D	0D	96	00	41	31	1F	1F	01	1F	01	20	41	31	21	07	00	00	00	6E	00
B6	A7	2F	B9	4F	00	04	A5	93	43	F4	AA	30	06	4E	76	B9	DB	9F	60	AF	00
F5	E9	DD	4F	F4	B0	00	82	16	40	90	55	81	42	C1	FF	FF	F8	5F	FF	FF	0F
FF	FF	FF	FF	FF	FC	01	FF	FF	F0	00	00	00	00	00	00	03	10	0C	68	D1	A3
46	8D	1A	34	68	D2	E5	4A	9B	3E	34	6A	13	63	52	AB	1A	35	58	D5	6A	55
AB	56	34	68	D1	A3	46	8D	1A	34	68	D1	A3	46	8D	1A	34	60	37	37	37	37

BUFR	<	b	Ä
4	}	x	~iF JY4
91334			<x
&x	F		Ä«
ñ A1		A1!	n
∂ß/π0	●iCÙ™0	Nvπ€ü`0	
iÈ>0Ü∞	Ç @êUÂBj`´´_´´		
´´´´´´´´´´	´´´´´´´´´´		h-f
Fç 4h“ÄJö>4j	cR’ 5X’jU		
´V4h-fFç 4h-fFç	4`7777		

47	52	49	42	00	00	66	01	00	00	1C	01	62	01	FF	80	33	6D	00	01	06	0C
05	0C	00	0C	00	C8	05	00	00	00	15	00	00	00	00	00	32	02	2B	0A	00	F8
01	90	80	33	C2	00	16	76	88	00	68	1A	00	76	F2	00	64	00	64	40	00	00
00	00	80	55	F0	80	9C	40	00	00	00	00	43	3E	B0	71	00	00	00	00	00	00
0C	08	80	11	3C	1F	09	7C	00	00	37	37	37	37								

GRIB	f	b	˘Ä3m
»		2	+ ´
éÄ3-	và h	vÚ d	d@
ÄU•Äú@		C>∞q	
Ä <	I	7777	



Made for machines, not humans !



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

ecCodes is a package developed by ECMWF which provides an application programming interface and a set of tools for decoding and encoding messages in the following formats:

- WMO FM-92 **GRIB** [edition 1](#) and [edition 2](#)
- WMO FM-94 **BUFR** [edition 3](#) and [edition 4](#)
- WMO GTS [abbreviated header](#) (only decoding).



<https://confluence.ecmwf.int/display/ECC/BUFR+tools>

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)

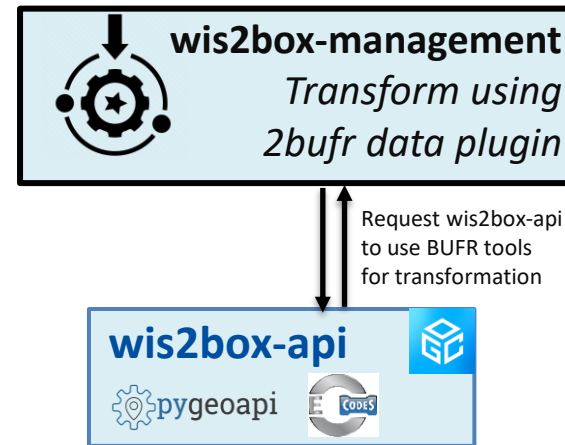
bufr_set (set values in a BUFR file)

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

BUFR tools in wis2box



‘wis2box-api’ container is based on a Docker image containing [ecCodes](#) software library ... and also contains several BUFR-conversion tools that work with ecCodes



BUFR tools used within wis2box-api available to be used standalone:

<https://github.com/World-Meteorological-Organization/csv2bufr>

<https://github.com/World-Meteorological-Organization/synop2bufr>

<https://github.com/World-Meteorological-Organization/bufr2geojson>

CSV-to-BUFR introduction

wis2box contains a built-in data-plugin for “CSV data converted to BUFR”

- Enables ingesting data in CSV format while publishing WIS2 notifications containing BUFR data
- Uses a mapping template to map input columns to BUFR codes

csv2bufr-transformation is provided by the ‘csv2bufr’ module that can also be used outside of the wis2box
<https://github.com/wmo-im/csv2bufr>

Plugin Configuration

Plugin Name
CSV data converted to BUFR

File Extension
CSV

Template
AWS

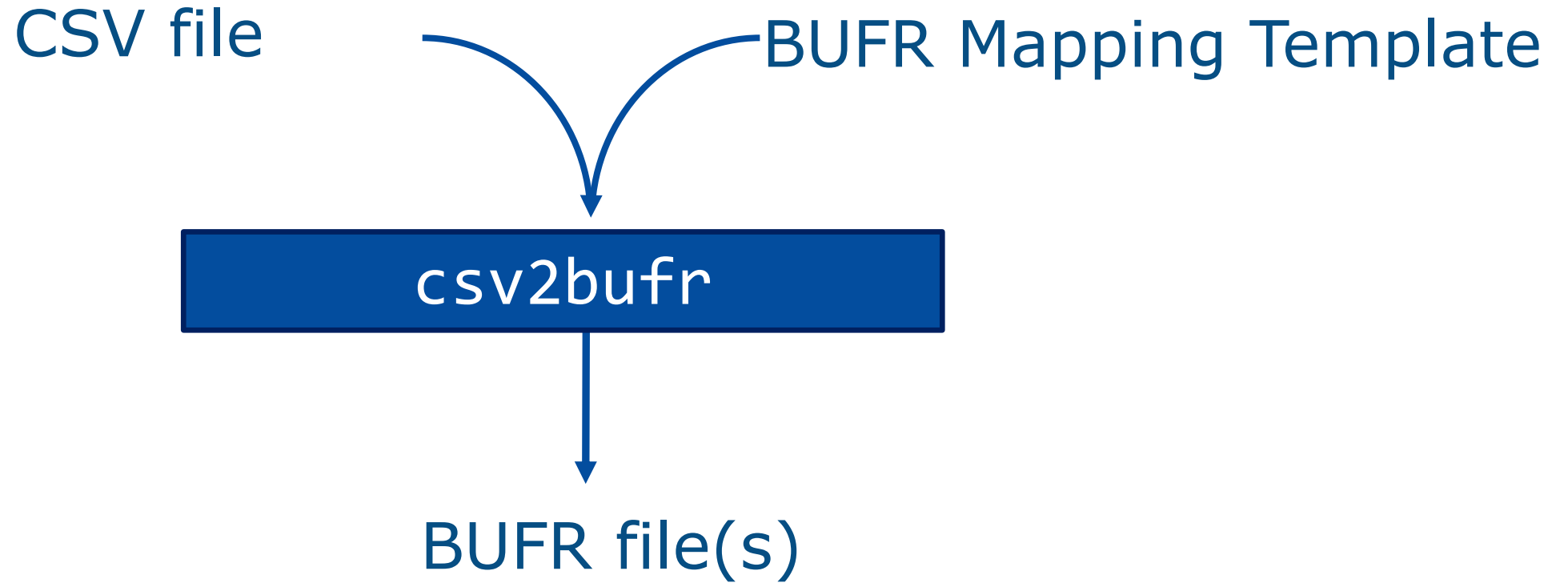
WIS2 Buckets
Incoming

File Pattern (Regex)
.*\.csv\$

☒ Notify

SAVE

CSV-to-BUFR key ingredients



BUFR mapping template

Template: JSON file defining mapping between columns in the input CSV data to codes encoded in the output BUFR data

... using the human-readable eccodes_key rather than the 6 digit BUFR FXXYYY code

```
"data": [
```

```
....
```

```
{ "eccodes_key": "#1#nonCoordinatePressure", "value": "data:station_pressure", "valid_min": "const:50000", "valid_max": "const:150000"},  
{ "eccodes_key": "#1#pressureReducedToMeanSeaLevel", "value": "data:msl_pressure", "valid_min": "const:50000", "valid_max": "const:150000"},  
{ "eccodes_key": "#1#nonCoordinateGeopotentialHeight", "value": "data:geopotential_height", "valid_min": "const:-1000", "valid_max": "const:130071"},  
{ "eccodes_key": "#1#heightOfSensorAboveLocalGroundOrDeckOfMarinePlatform", "value": "data:thermometer_height", "valid_min": "const:0", "valid_max": "const:655.35"},  
{ "eccodes_key": "#1#airTemperature", "value": "data:air_temperature", "valid_min": "const:193.15", "valid_max": "const:333.15"},  
... ]
```

Data CSV file

BUFR Mapping template

csv2bufr

BUFR file(s)

BUFR mapping template

valid_min: Minimum tolerable value

valid_max: Maximum tolerable value

csv2bufr uses 'valid_min' and 'valid_max' to catch input errors: invalid values will not be encoded in the BUFR

```
"data": [
```

```
....
```

```
{ "eccodes_key": "#1#nonCoordinatePressure", "value": "data:station_pressure", "valid_min": "const:50000", "valid_max": "const:150000"},  
{ "eccodes_key": "#1#pressureReducedToMeanSeaLevel", "value": "data:msl_pressure", "valid_min": "const:50000", "valid_max": "const:150000"},  
{ "eccodes_key": "#1#nonCoordinateGeopotentialHeight", "value": "data:geopotential_height", "valid_min": "const:-1000", "valid_max": "const:130071"},  
{ "eccodes_key": "#1#heightOfSensorAboveLocalGroundOrDeckOfMarinePlatform", "value": "data:thermometer_height", "valid_min": "const:0", "valid_max": "const:655.35"},  
{ "eccodes_key": "#1#airTemperature", "value": "data:air_temperature", "valid_min": "const:193.15", "valid_max": "const:333.15"},  
... ]
```

Data CSV file

*air_temperature
value=29.5*

BUFR Mapping template

csv2bufr

*WARNING: Value (29.5) out of valid range
(193.15 - 333.15); Element set to missing*

BUFR file(s)

The AWS template

AWS Template:

Standardized CSV format to ingest data from Automatic Weather Stations in support of GBON reporting requirements

The format is intended for use with automatic weather stations reporting a minimum number of parameters, including pressure, air temperature and humidity, wind speed and direction and precipitation

Based on SI units, with no unit prefixes, e.g. Pa rather than hPa, Kelvin rather than degrees Celsius etc

Template = AWS in the Plugin Configuration
refers to the '**aws-template.json**' as defined in
<https://github.com/wmo-im/csv2bufr-templates>

Plugin Configuration

Plugin Name: CSV data converted to BUFR

File Extension: CSV

Template: AWS

WIS2 Buckets: Incoming

File Pattern (Regex): *.csv\$

Notify: ☒

SAVE

The DAYCLI template

DAYCLI Template:

Standardized CSV format for converting daily climate data to BUFR sequence 307075

The format is intended for use with Climate Data Management Systems to publish data on WIS2

Requirement for daily climate observations to monitor extremes

Daily observations of:

- Minimum, maximum and average temperature over 24 hours period
- Total accumulated precipitation over 24 hours period
- Total snow depth at time of observation
- Depth of fresh snow over 24 hours period

Recognition of different reporting practices by Members, explicit reporting of 24 hours period used

Additional metadata: method of calculating average temperature; sensor and station heights; exposure and measurement quality classification

Template = AWS in the Plugin Configuration
refers to the '**daycli-template.json**' as defined in
<https://github.com/wmo-im/csv2bufr-templates>

Plugin Configuration

Plugin Name
CSV data converted to BUFR

File Extension
CSV

Template
DayCLI

WIS2 Buckets
Incoming

File Pattern (Regex)
.*\.csv\$

☒ Notify

SAVE

SYNOP-to-BUFR Key Ingredients

SYNOP FM-12 text file

Station list CSV file

synop2bufr

csv2bufr

pymetdecoder

synop2bufr

<https://github.com/wmo-im/synop2bufr>

csv2bufr

<https://github.com/wmo-im/csv2bufr>

pymetdecoder

<https://github.com/antarctica/pymetdecoder>

UK Research and Innovation (UKRI), 2021, British Antarctic Survey

BUFR file(s)

Example Files

AAXX = data from fixed
land station

FM-12 SYNOP reports

SMR001 YRBK 211200 **YY = 21 of the month**
GG = 12 hour of observation
iw = 1 Wind speed obtained from anemometer in m/s
 AAXX 21121
 15015 02999 02501 10103 21090 39765 42952 57020 60001 333 4/000 55310
 0//// **TSI**
 22591 3//// 60007 91003 91104=
 15020 02997 23104 10130 21075 30177 40377 58020 60001 81041 333 4/000
 55310 **TSI**
 0//// 22547 3//// 60007 91008 91111=

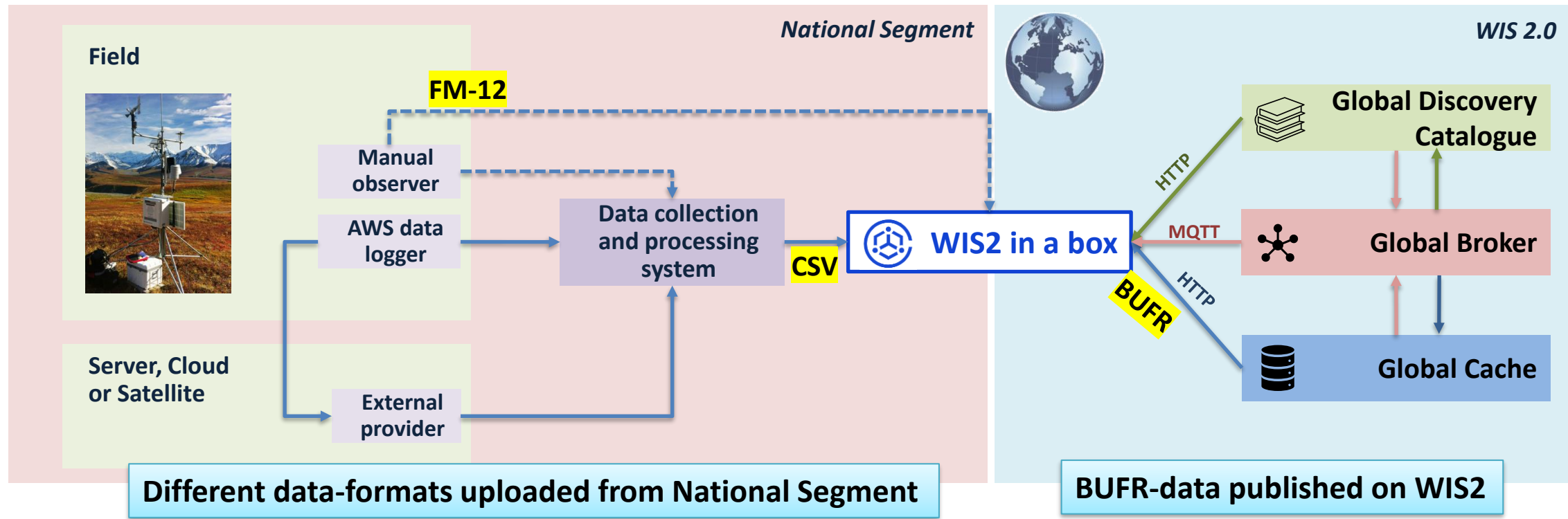
Station list metadata

station_name	wigos_station_identifier	traditional_station_identifier	facility_type	latitude	longitude	elevation
OCNA SUGATAG	0-20000-0-15015	15015	Land (fixed)	47.7770616	23.9404603	503
BOTOSANI	0-20000-0-15020	15020	Land (fixed)	47.7356532	26.6455502	161
IASI	0-20000-0-15090	15090	Land (fixed)	47.1633333	27.6272222	74.29
CEAHLAU TOACA	0-20000-0-15108	15108	Land (fixed)	46.97751	25.94994	1897
CLUJ-NAPOCA	0-20000-0-15120	15120	Land (fixed)	46.7777705	23.5713053	410
BACAU	0-20000-0-15150	15150	Land (fixed)	46.5577778	26.8966667	174
MIERCUREA CIUC	0-20000-0-15170	15170	Land (fixed)	46.3713167	25.7726167	661
ARAD	0-20000-0-15200	15200	Land (fixed)	46.1335164	21.3536215	116.59
DEVA	0-20000-0-15230	15230	Land (fixed)	45.864923	22.8988062	240
SIBIU	0-20000-0-15260	15260	Land (fixed)	45.79018	24.036245	450
VARFU OMU	0-20000-0-15280	15280	Land (fixed)	45.4457928	25.456691	2504
CARANSEBES	0-20000-0-15292	15292	Land (fixed)	45.41667	22.22917	241
GALATI	0-20000-0-15310	15310	Land (fixed)	45.4729181	28.0323011	69
TULCEA	0-20000-0-15335	15335	Land (fixed)	45.1905065	28.8241608	4.36
RAMNICU VALCEA	0-20000-0-15346	15346	Land (fixed)	45.0888211	24.3628139	237
BUZAU	0-20000-0-15350	15350	Land (fixed)	45.1326633	26.8517319	97
SULINA	0-20000-0-15360	15360	Land (fixed)	45.1623111	29.7268286	69
DROBETA-TURNU SEVERIN	0-20000-0-15410	15410	Land (fixed)	44.6264587	22.6260737	77
BUCURESTI BANEASA	0-20000-0-15420	15420	Land (fixed)	44.510433	26.0781904	90

wis2box data plugins

wis2box data plugins use the BUFR tools to enable data transformation prior to publication

- **csv2bufr** enables any system to prepare a data-extract without needing local BUFR conversion tools
- **synop2bufr** enables direct publication of FM-12 synop reports from manual observers



Practical exercise

PRACTICAL EXERCISE:

Become familiar with the data conversion tools available in wis2box:

<https://training.wis2box.wis.wmo.int/practical-sessions/data-conversion-tools/>

Thank you

wmo.int



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METEOROLOGICAL
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