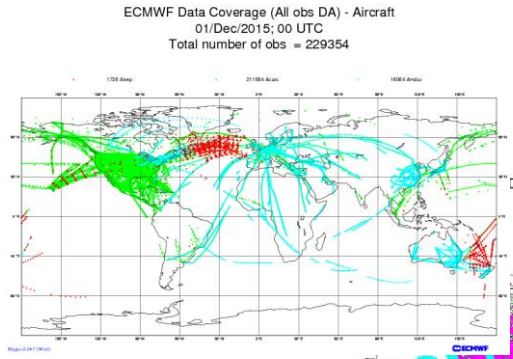
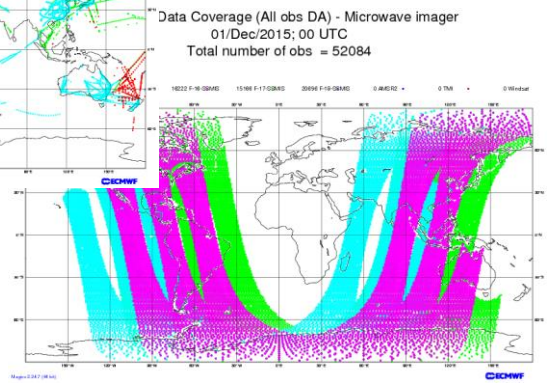
WMO Binary Codes and data conversion tools in the wis2box

WMO Binary codes

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

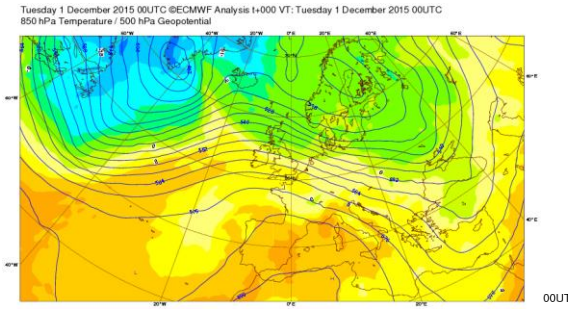
- a flexible binary format
- mainly used to encode in situ and satellite observations
- can also represent forecast data (e.g. tropical cyclone tracks)

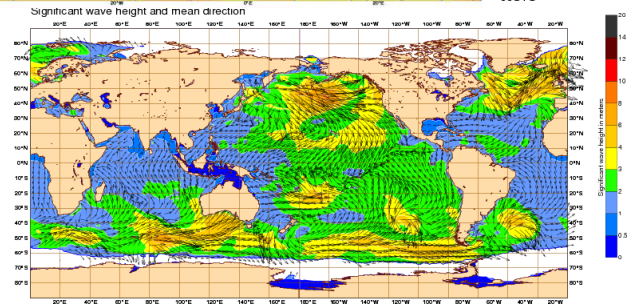




GRIB (General Regularly-distributed Information in Binary form)

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





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WMO Binary Codes: BUFR

How BUFR Works:

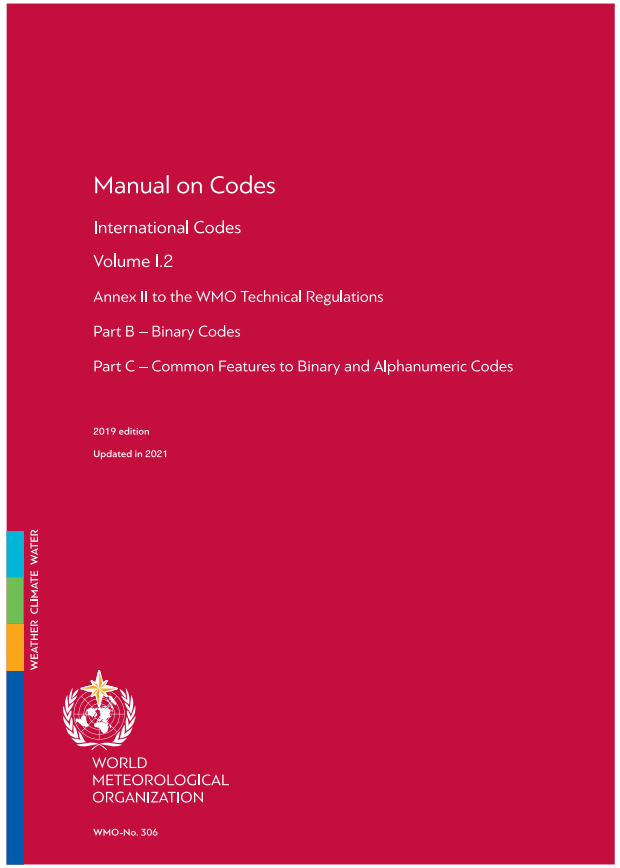
- **BUFR message** consists of a **header and a body containing data and metadata**.
- **BUFR descriptors** define how data is structured and encoded within a BUFR message
- **Compression for efficient storage** to reduce transmission times.

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



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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

```
01001010111010100101010101010
0010001010101010001010100
0101010010010100101001010
1010101010111100010101001001
```

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 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
```

```
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
```

Made for machines, not humans !

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ecCodes

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).

ecCodes BUFR tools

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)

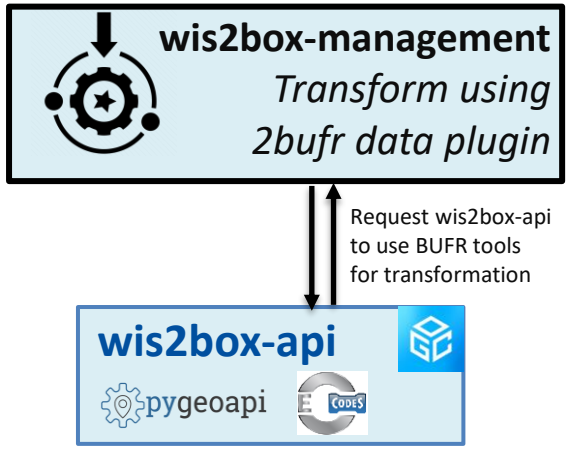
bufr_get (get values form a BUFR file)

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 tools that work with ecCodes



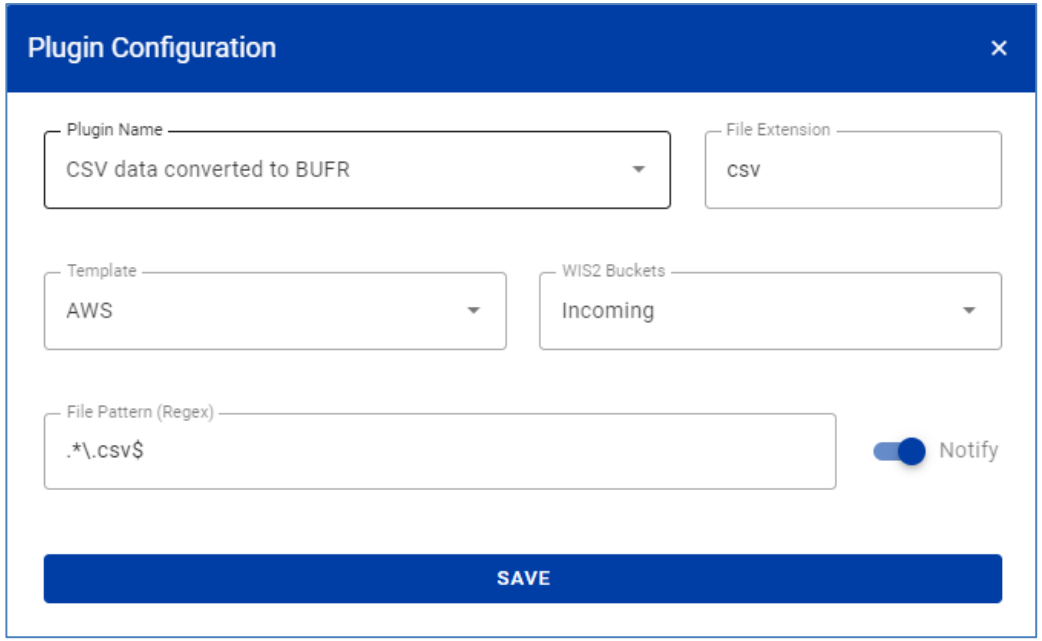
BUFR tools used within wis2box-api available to be used standalone:
https://github.com/World-Meteorological-Organization/csv2bufr
https://github.com/World-Meteorological-Organization/synop2bufr
https://github.com/World-Meteorological-Organization/bufr2geojson

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



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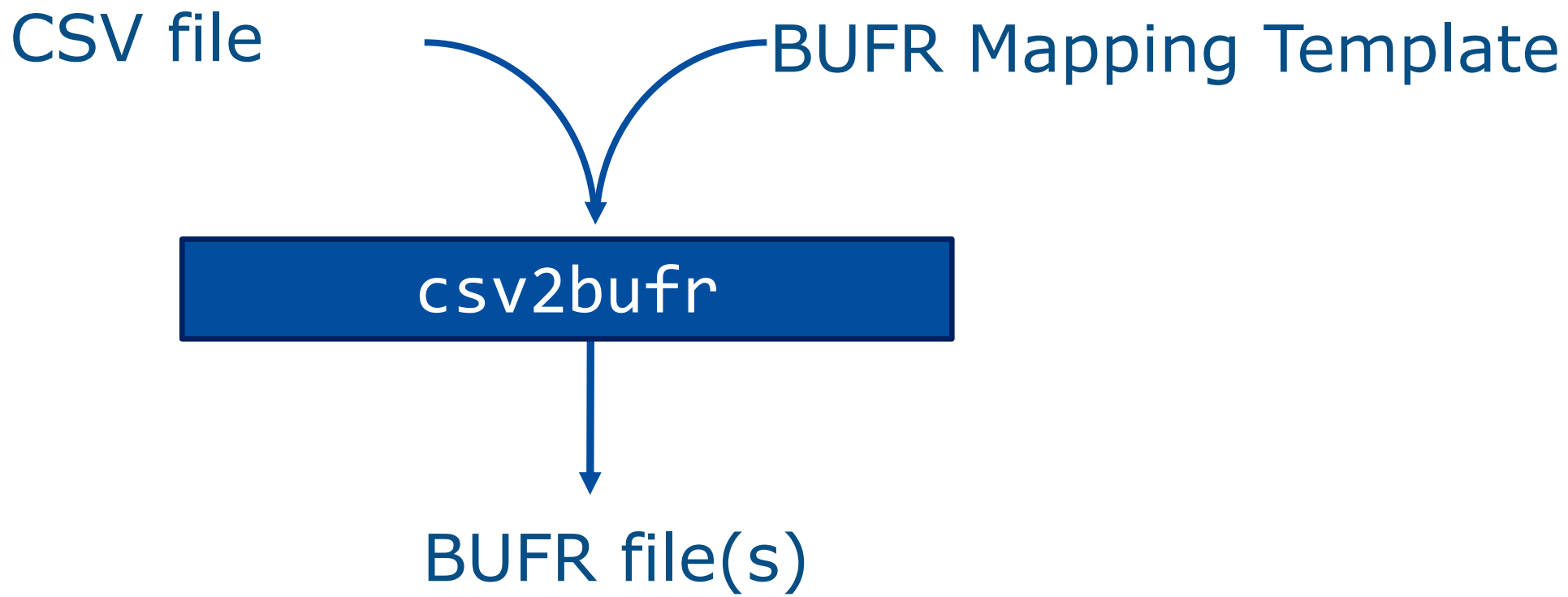
CSV-to-BUFR key ingredients

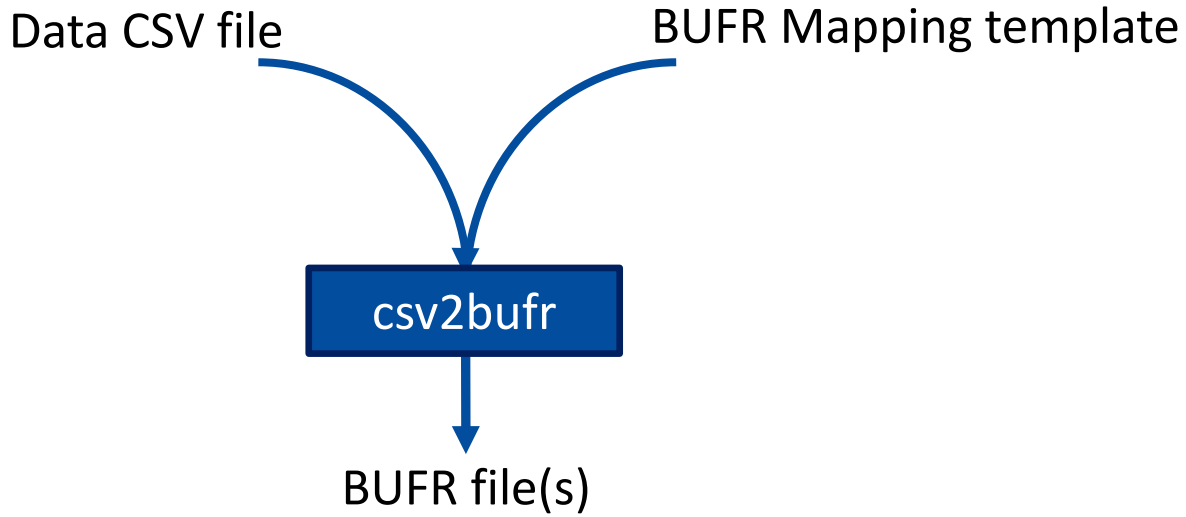


BUFR mapping template

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"},
   ... ]
```

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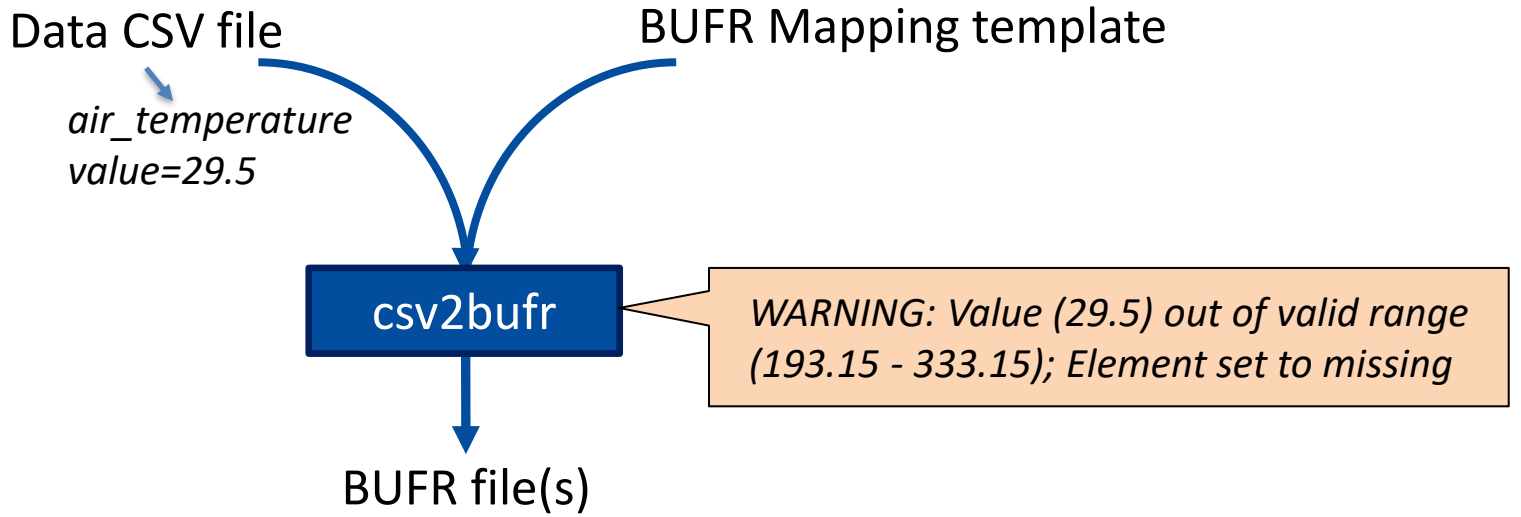
BUFR mapping template

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"},
   ... ]
```

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The AWS template

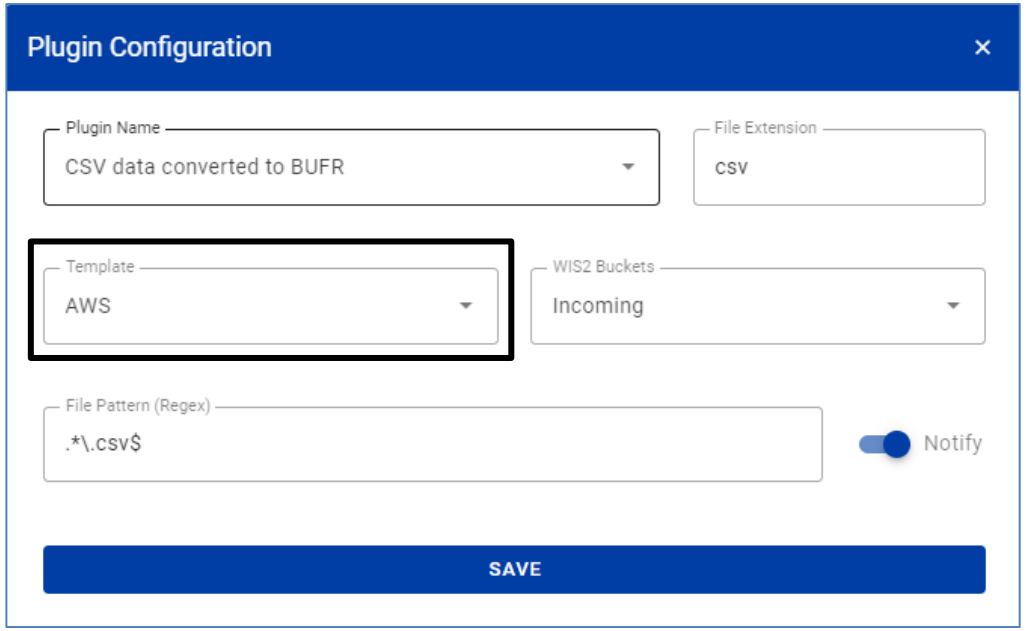
AWS Template:

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



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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

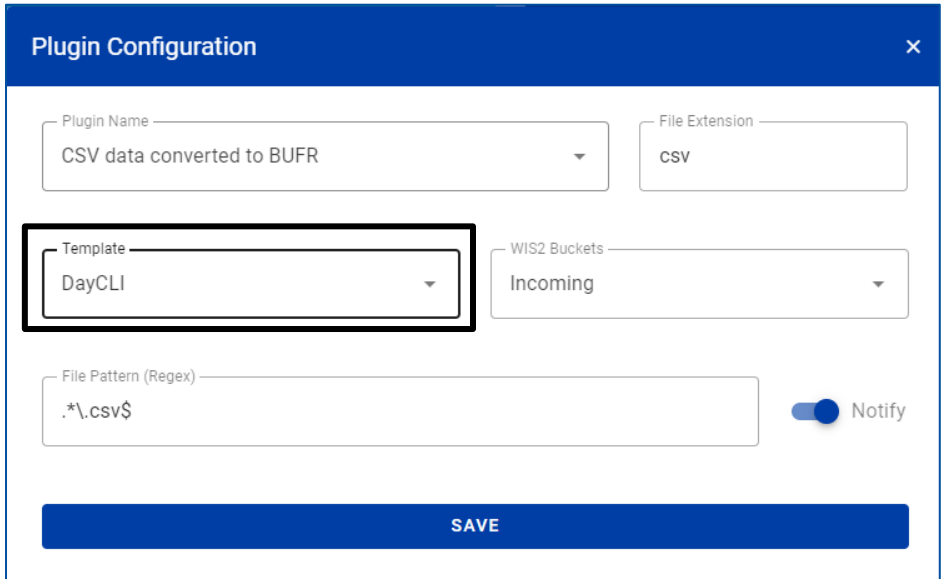
Daily observations of:

- 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



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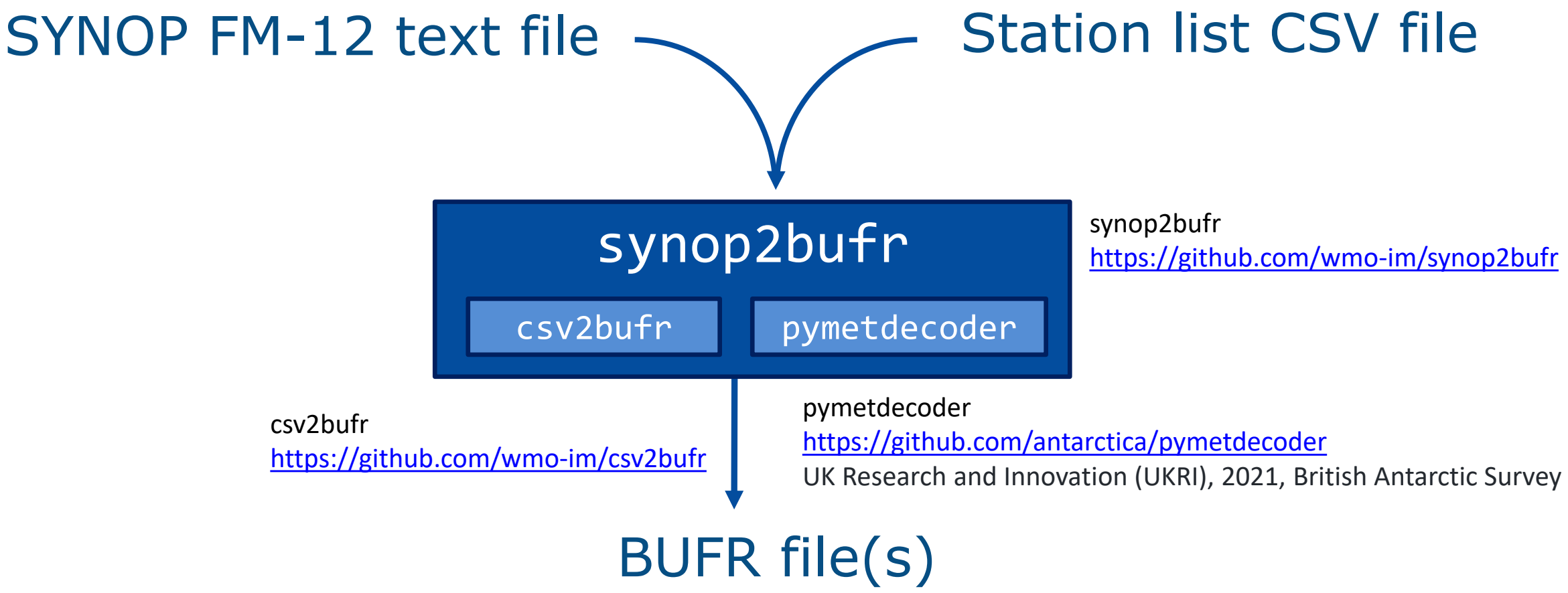
SYNOP-to-BUFR Key Ingredients



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

Example Files

FM-12 SYNOP reports

AAXX = data from fixed land station

```
SMRO01 YRBK 211200
AAXX 21121
15015 02999 02501 10103 21090 39765 42952 57020 60001 333 4/000 55310
0////
22591 3//// 60007 91003 91104=
15020 02997 23104 10130 21075 30177 40377 58020 60001 81041 333 4/000
55310
0//// 22547 3//// 60007 91008 91111=
```

YY = 21 of the month

GG = 12 hour of observation

iw = 1 Wind speed obtained from anemometer in m/s

TSI

TSI

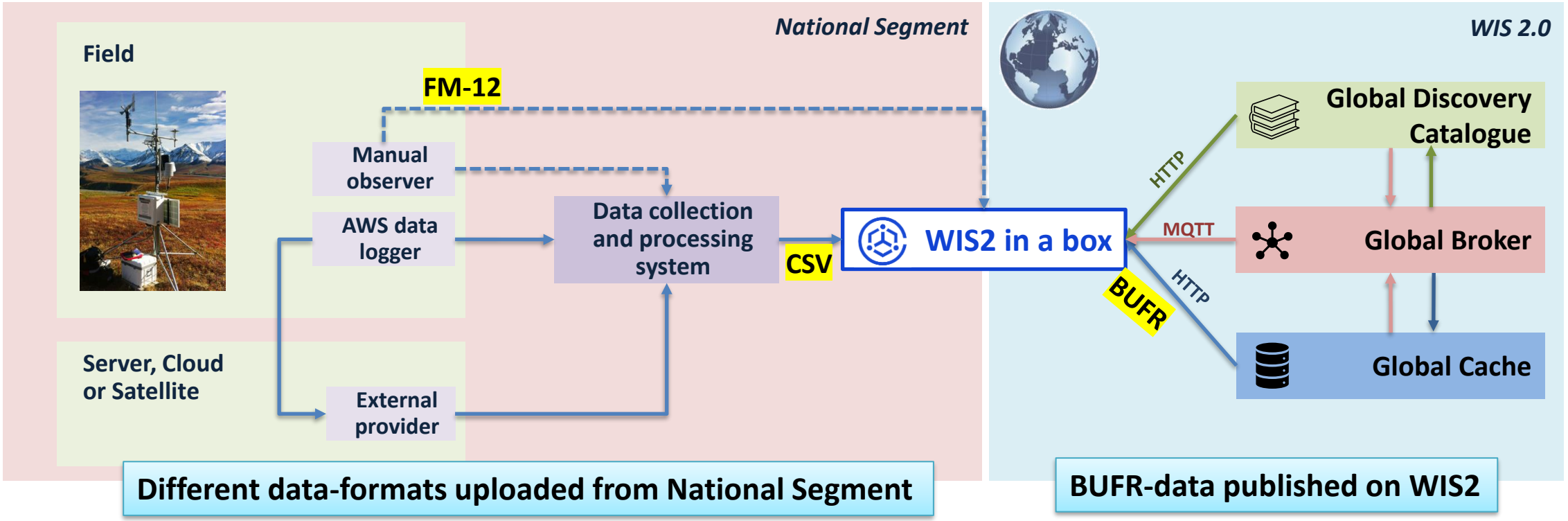
Station list metadata

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



Thank you
شكرًا لك

wmo.int

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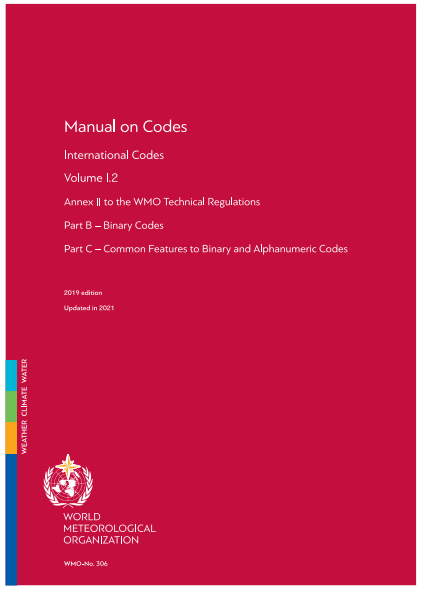
Vocabulary of key names from BUFR tables



https://confluence.ecmwf.int/display/ECC/BUFR+tables

ecCodes tables

BUFR tables

Semantics

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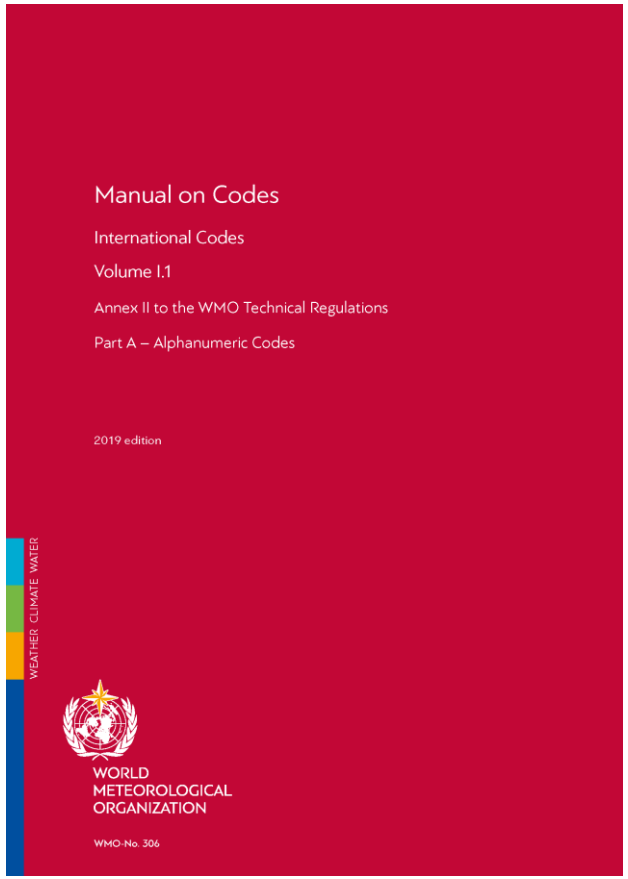
SYNOP code form

Manual on Codes Vol. I.1



AAXX = fixed land station
BBXX = sea station
OOXX = mobile land station

YY = day of the month (no month, year)
GG = time of observations rounded at the nearest hour
i_w = units of wind speed and observed/estimated

FM 12–XIV Ext. SYNOP	**Report of surface observation from a fixed land station**
FM 13–XIV Ext. SHIP	**Report of surface observation from a sea station**
FM 14–XIV Ext. SYNOP MOBIL	**Report of surface observation from a mobile land station**

C O D E F O R M :

Traditional Station Identifier (TSI)

SECTION 0	$M_iM_iM_jM_j$	D . . . . D**** or $A_1b_wn_bn_bn_b$**	$YYGGi_w$	IIiii* or $99L_aL_aL_a$ $Q_cL_oL_oL_oL_o$****	$MMMU_{La}U_{Lo}$***	$h_0h_0h_0h_0i_m$***		
SECTION 1	i_Ri_xhVV	Nddff	(00fff)	$1s_nTTT$	$2s_nT_dT_dT_d$ or 29UUU	$3P_0P_0P_0P_0$		
	4PPPP or $4a_3hhh$	5appp	$6RRRt_R$	$7wwW_1W_2$ or $7w_aw_aW_{a1}W_{a2}$	$8N_hC_LC_MC_H$	9GGgg		
SECTION 2	$222D_sv_s$	$(0s_sT_wT_wT_w)$	$(1P_{wa}P_{wa}H_{wa}H_{wa})$	$(2P_wP_wH_wH_w)$	$((3d_{w1}d_{w1}d_{w2}d_{w2})$			
	$(4P_{w1}P_{w1}H_{w1}H_{w1})$	$(5P_{w2}P_{w2}H_{w2}H_{w2}))$	($6I_sE_sE_sR_s$ or ICING + plain language)					
	$(70H_{wa}H_{wa}H_{wa})$	$(8s_wT_bT_bT_b)$	(ICE + $c_iS_ib_iD_iz_i$ or plain language)					
SECTION 3	333	(0 . . . .)	$(1s_nT_xT_xT_x)$	$(2s_nT_nT_nT_n)$	(3Ejjj)	(4E´sss)	$(5j_1j_2j_3j_4$ $(j_5j_6j_7j_8j_9))$	
	$(6RRRt_R)$	$(7R_{24}R_{24}R_{24}R_{24})$	$(8N_sCh_sh_s)$	$(9S_PS_PS_pS_p)$				
	(80000 (0 . . . .)	(1 . . . .) . . . .)						
SECTION 4	444	N´C´H´H´C_t						
SECTION 5	555	Groups to be developed nationally						

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