

---

**csv2bufr**

***Release 0.1.0***

**World Meteorological Organization (WMO)**

**2022-05-30**



## TABLE OF CONTENTS:

<b>1</b>	<b>Overview</b>	<b>3</b>
<b>2</b>	<b>Installation</b>	<b>5</b>
2.1	Dependencies . . . . .	5
2.2	Installation . . . . .	5
<b>3</b>	<b>Quick start</b>	<b>7</b>
3.1	Command line interface . . . . .	7
3.2	API . . . . .	9
<b>4</b>	<b>Anatomy of a BUFR4 message</b>	<b>11</b>
<b>5</b>	<b>BUFR4 Descriptors</b>	<b>13</b>
5.1	Introduction . . . . .	13
5.2	Format of BUFR descriptors . . . . .	13
5.3	Replication / repetition . . . . .	14
5.4	Scope of descriptors . . . . .	15
5.5	Commonly used sequences . . . . .	15
5.6	Further information . . . . .	15
<b>6</b>	<b>BUFR template mapping</b>	<b>17</b>
6.1	inputDelayedDescriptorReplicationFactor . . . . .	18
6.2	bufr_element . . . . .	18
6.3	Units . . . . .	19
6.4	Schema . . . . .	20
<b>7</b>	<b>Examples</b>	<b>23</b>
7.1	Data file (example-data.csv) . . . . .	23
7.2	Metadata file (example-metadata.json) . . . . .	23
7.3	Creating a new mapping file . . . . .	24
7.4	Customising the mapping file (bufr-mappings-edited.json) . . . . .	32
7.5	Transformation . . . . .	35
<b>8</b>	<b>Development</b>	<b>37</b>
<b>9</b>	<b>Support</b>	<b>39</b>
<b>10</b>	<b>License</b>	<b>41</b>
10.1	Software . . . . .	41
10.2	Documentation . . . . .	45



**Author**

World Meteorological Organization (WMO)

**Contact**

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

**Release**

0.1.0

**Date**

2022-05-30



## **OVERVIEW**

The csv2bufr Python module contains both a Command Line Interface (CLI) and an API to convert data stored in a CSV file to the WMO BUFR data format. More information on the BUFR format can be found in the [WMO Manual on Codes, Volume I.2](#)





## INSTALLATION

### 2.1 Dependencies

The csv2bufr module relies on the [ecCodes](#) software library to perform the BUFR encoding. This needs to be installed prior to installing any of the Python packages, instructions can be found on the ecCodes documentation pages: <https://confluence.ecmwf.int/display/ECC>.

The following Python packages are required by the csv2bufr module:

- [eccodes](#) (NOTE: this is separate from the ecCodes library)
- [jsonschema](#)
- [jsonpath\\_ng](#)

Additionally, the command line interface to csv2bufr requires:

- [click](#)

For convenience and to download station metadata from OSCAR/Surface the pyoscar Python module is recommended.

- [pyoscar](#)

All the above packages can be installed by running:

```
pip install -r requirements.txt
```

### 2.2 Installation

#### 2.2.1 Docker

The quickest way to install and run the software is via a Docker image containing all the required libraries and Python modules:

```
docker pull wmoim/csv2bufr
```

This installs a [Docker image](#) based on Ubuntu and includes the ecCodes software library, dependencies noted above and the csv2bufr module (including the command line interface).

## 2.2.2 Source

Alternatively, csv2bufr can be installed from source. First clone the repository and navigate to the cloned folder / directory:

```
git clone https://github.com/wmo-im/csv2bufr.git -b dev
cd csv2bufr
```

If running in a Docker environment, build the Docker image and run the container:

```
docker build -t csv2bufr .
docker run -it -v ${pwd}:/app csv2bufr
cd /app
```

The above step can be skipped if not using Docker. Now install the module and test:

```
python3 setup.py install
csv2bufr --help
```

The following output should be shown:

```
Usage: csv2bufr [OPTIONS] COMMAND [ARGS]...

  csv2bufr

Options:
  --version  Show the version and exit.
  --help     Show this message and exit.

Commands:
  data      data workflows
  mappings  stored mappings
```

## QUICK START

The `csv2bufr` Python module contains both a command line interface and an API to convert data stored in a CSV file to the WMO BUFR data format. For example, the command line interface reads in data from a CSV file, converts it to BUFR and writes out the data to the specified directory. e.g.:

```
csv2bufr data transform <my-csv-file.csv> \  
  --bufr-template <csv-to-bufr-mapping.json> \  
  --station-metadata <oscar-metadata-file.json> \  
  --output <output-directory-path>
```

This command is explained in more detail below.

### 3.1 Command line interface

The following example transforms the data in file `my-csv-file.csv` to BUFR using template `csv-to-bufr-mapping.json` and writes the output to directory `output-directory-path`:

```
csv2bufr data transform <my-csv-file.csv> \  
  --bufr-template <csv-to-bufr-mapping.json> \  
  --station-metadata <oscar-metadata-file.json> \  
  --output-dir <output-directory-path>
```

The command is built on the [Python Click module](#) and is formed of three components (`csv2bufr data transform`), 1 argument and 3 options (specified by `-`). The argument specifies the file to process and the options various configuration files to use.

1. `my-csv-file.csv`: argument specifying the CSV data file to process
2. `--bufr-template csv-to-bufr-mapping.json`: option followed by the bufr mapping template to use
3. `--station-metadata oscar-metadata-file.json`: option followed by name of json file containing the station metadata
4. `--output-dir output-directory-path`: option followed by output directory to write BUFR file to. The output filename is set using the md5 checksum of the BUFR data to ensure uniqueness, future versions will use the WIGOS ID and timestamp of the data to set the filename.

The output BUFR files can be validated using a tool such as the [ECMWF BUFR validator](#).

### 3.1.1 Input CSV file

Currently, a single station per file is supported with each row treated as a separate record and one BUFR file per record created. The format of the input CSV file has a few requirements:

- A comma (i.e. ,) must be used as the delimiter.
- Strings must be quoted.
- Missing values must be encoded as “None”.
- The final row in the file must contain data and not be a new line.
- The timestamp of the records must be separated into components, i.e. year, month, day etc must each be in a separate column.
- The date/time elements should be in Universal Time Coordinated (UTC).

### 3.1.2 BUFR mapping template (--bufr-template)

The mapping from CSV to BUFR is specified in a JSON file (see the [BUFR template mapping page](#)).

### 3.1.3 Station metadata (--station-metadata)

In addition to the input CSV data file and BUFR template file a json file containing the station metadata is also required. At a minimum this file must contain the [WIGOS station identifier](#) as per the example below:

```
{
  "wigosIds": [
    {
      "wid": "<series>-<issuer>-<issue-number>-<local-identifier>"
    }
  ]
}
```

Where the parameters in brackets (<>) are replaced with their respective values. More information on the WIGOS identifiers can also be found in the [Guide to the WMO Integrated Observing System](#), section 2 (WMO-No. 1165).

If the station has been registered within the WMO OSCAR/Surface database the metadata file can be downloaded using the [pyoscar](#) Python package. For example, to download station metadata for the station on Bird Island, South Georgia, with the WIGOS station identifier “0-20008-0-SGI” the following would be used:

```
pyoscar station --identifier 0-20008-0-SGI > 0-20008-0-SGI.json
```

This writes the output to the file 0-20008-0-SGI.json as specified by the redirect (>).

## 3.2 API

The command line interface uses the `transform` function from the `csv2bufr` module. This can be used directly, e.g.:

```
# import modules
import json
from csv2bufr import transform

# load data from file
with open("my-csv-file.csv") as fh:
    data = fh.read()

# load mapping
with open("csv-to-bufr-mapping.json") as fh:
    mapping = json.load(fh)

# load metadata
with open("oscar-metadata-file.json") as fh:
    metadata = json.load(fh)

# call transform function
result = transform(data, metadata, mapping)

# iterate over items
for item in result:
    # get id and phenomenon time to use in output filename
    wsid = item["_meta"]["wigos_id"] # WIGOS station ID
    timestamp = item["_meta"]["data_date"] # phenomenonTime as datetime object
    timestamp = timestamp.strftime("%Y%m%dT%H%MZ") # convert to string
    # set filename
    output_file = f"{wsid}_{timestamp}.bufr4"
    # save to file
    with open(output_file, "wb") as fh: # note binary write mode
        fh.write(item["bufr4"])
```

The `transform` function returns an iterator that can be used to iterate over each line in the data file. Each item returned contains a dictionary with the following elements:

- `item["bufr4"]` binary BUFR data
- `item["_meta"]` dictionary containing metadata elements
- `item["_meta"]["md5"]` the md5 checksum of the encoded BUFR data
- `item["_meta"]["identifier"]` identifier for result (set combination of `wigos_id` and `data_date`)
- `item["_meta"]["wigos_id"]` WIGOS station identifier
- `item["_meta"]["data_date"]` characteristic date of data contained in result (from BUFR)
- `item["_meta"]["originating_centre"]` originating centre for data (from BUFR)
- `item["_meta"]["data_category"]` data category (from BUFR)



## ANATOMY OF A BUFR4 MESSAGE

In order to understand the mapping between a CSV file and its BUFR encoding it is first helpful to understand the anatomy of a BUFR message. A BUFR message is encoded in binary and contains 6 sections as shown in the diagram below. The ecCodes keys for the different elements are also shown as these are used to set certain elements (highlighted in red) as part of the conversion to BUFR. The non-highlighted elements (including those without an ecCodes key) are either set by the eccodes module based on the data, have a default value or can be omitted / set to missing.

The information contained in Sections 0, 1, and 3 are essentially metadata specifying:

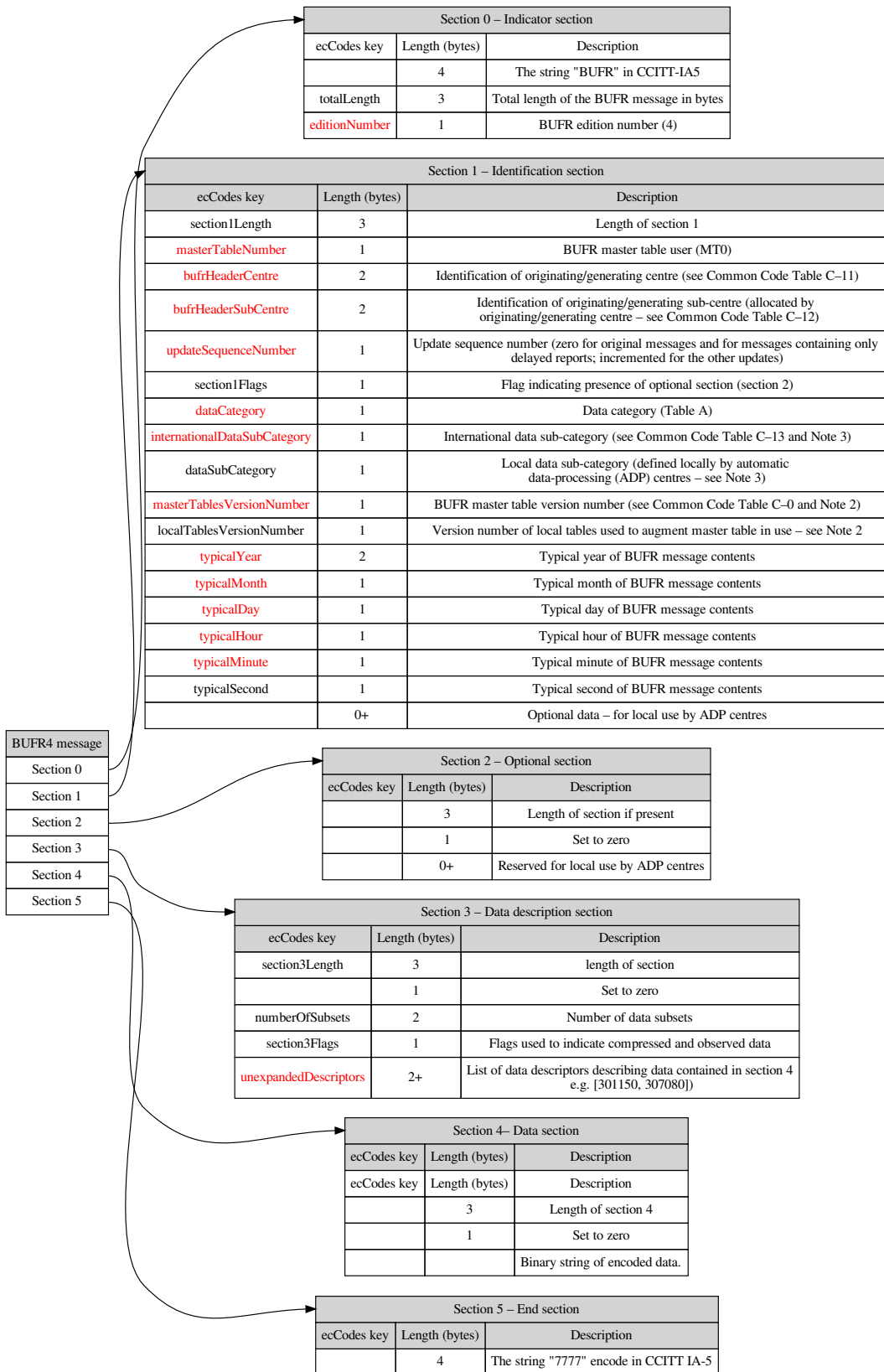
- the version of the BUFR tables used (editionNumber, masterTableNumber, masterTableVersionNumber);
- where the data have come from (bufrHeaderCentre, bufrHeaderSubCentre);
- the typical time of the observation (typicalYear ... typicalSecond);
- the type of data and what parameters are included (dataCategory, internationalDataSubCategory and unexpandedDescriptors).

These are all specified in the BUFR template mapping file.

The edition number and master table number should be 4 and 0 respectively. BUFR edition 4 is the latest version and whilst it is possible to define new BUFR tables for different application areas only Master Table 0 (MT0) has been defined (meteorology). The tables in MT0 are updated approximately every 6 months as part of the WMO fast track process and the authoritative source can be found in the [WMO Manual on Codes, Volume I.2](#). Updates to this can be delayed and the latest version, including machine readable tables, can be found at <https://github.com/wmo-im/BUFR4/releases> and it is recommended to use the most recent release. The master branch contains the current working copy of the tables and is subject to change.

The BUFR header centre and bufr header sub centre are specified in Common Code Tables C-11 and C-12 respectively. The typical time of observation (typicalYear ... typicalSecond) should be determined based on the data to be encoded. Within the csv2bufr module and CLI only a single observation / weather report is encoded per file and so these should be set to those columns in the CSV specifying the year, month, day etc. More information is provided in the page on the BUFR template mapping ([link to follow](#)).

The data category should be set according to BUFR Table A, i.e. 0 for “Surface data - land” and 1 for “Surface data - sea”. The international data sub category should be set according to Common Code Table C-13. The unexpanded descriptors specifies the data to be encoded in the data section is comprised of a list of the BUFR descriptors. These descriptors are detailed further on the next page (BUFR descriptors).





## BUFR4 DESCRIPTORS

### 5.1 Introduction

As part of the BUFR format, a list of the included parameters is embedded within the file using the `unexpandedDescriptors` element of Section 3. This element takes a list of the parameters to be included and the order of those parameters. For example, the unexpanded descriptor list (in text, see format of descriptors below):

```
["unexpandedDescriptors"] = ["wigosID", "year", "month", "day", "hour", "minute", \
                             "latitude", "longitude", "pressure reduced to mean sea_↵
↵level"]
```

would specify that the station identifier (`wigosID`) followed by the date, time, location and then the pressure reduced to mean sea level would be included in the data section. For conciseness, aliases (or sequences in BUFR terminology) exist to group commonly reported parameters together, for example grouping the year, month and day together in the group date. Using sequences, the above example becomes:

```
["unexpandedDescriptors"] = ["wigosID", "date", "time", "location", "pressure reduced to_↵
↵mean sea level"]
```

where

```
["date"] = ["year", "month", "day"]
["time"] = ["hour", "minute"]
["location"] = ["latitude", "longitude"]
```

These sequences form building blocks that can be used to create much longer sequences using a small number of descriptors.

### 5.2 Format of BUFR descriptors

Whilst text strings have been used above to represent the parameters to report this has been done for ease of reading and explanation. Within the BUFR format these are specified by 6 digit codes of the form `FXXYYY`, with each of `F`, `XX` and `YYY` having specific meaning.

- `F`: Type of BUFR descriptor
  - 0: element descriptor (BUFR Table B);
  - 1: replication (or repetition) descriptor;
  - 2: operator (BUFR Table C);
  - 3: sequence descriptor (BUFR Table D)

- XX: Sub-table (class) within type of descriptor
- YYY: Index within in sub-table.

As an example, the table below shows the first few entries from BUFR Table B 01.

For the above example, using the FXXYYY notation, the list of abbreviated (or unexpanded) descriptors becomes:

```
["unexpandedDescriptors"] = [301150, 301011, 301012, 301023, 010051]
```

where:

```
[301150] = [001125, 001126, 001127, 001128] # (wigosID)
          = ["WIGOS identifier series", "WIGOS identifier issuer", "WIGOS identifier issue_
↪number", "WIGOS local identifier"]
[301011] = [004001, 004002, 004003] # (date)
          = ["year", "month", "day"]
[301012] = [004004, 004005] # (time)
          = ["hour", "minute"]
[301023] = [ 005002, 006002] # (location)
          = ["latitude", "longitude"]
[010051] = ["pressure reduced to mean sea level"]
```

## 5.3 Replication / repetition

Within the BUFR format, elements can be repeated using the replication descriptors (F=1 in FXXYYY). For example, we may want to repeat temperature and humidity measurements as part of an atmospheric profile or, alternatively, the daily minimum and maximum temperatures within a month. In some cases we may know the number of repetitions before encoding and all data of the same type may have the same number of repetitions. In this case the number of replications can be set before hand and included in the sequence. In other cases, there may be a variable number of repetitions and so the number is set at the time of encoding.

When using the replication descriptor (1XXYYY), the XX component indicates the number of following descriptors to repeat and the YYY component the number of replications. For example, to repeat the day of month, maximum and minimum temperatures 5 times we would use:

$$[\text{unexpandedDescriptors}] = \left[ \overbrace{103005}^{\text{repeat (1) next 3 (03) descriptors 5 (005) times}}, \overbrace{004003, 012016, 012017}^{\text{descriptors to be repeated}} \right]_{\text{FXXYYY}}$$

In expanded form, or without using the replication, this would be equivalent to:

$$[\text{expandedDescriptors}] = [ 004003, 012016, 012017, \quad (5.1)$$

$$004003, 012016, 012017, \quad (5.2)$$

$$004003, 012016, 012017, \quad (5.3)$$

$$004003, 012016, 012017, \quad (5.4)$$

$$004003, 012016, 012017] \quad (5.5)$$

If we do not know the number of replications, or there can be a variable number of replications, for a given sequence of descriptors we can set the YYY element (number of replications) to zero and follow the replication descriptor with a delayed replication factor.

$$[\text{unexpandedDescriptors}] = \left[ \overbrace{103000}^{\text{(repeat (1) next 3 (03) items n time)}}, \overbrace{031001}^{\text{(delayed number (n) of replications)}}, \overbrace{004003, 012016, 012017}^{\text{(descriptors to be repeated)}} \right]_{\text{replication and delayed replication factor}}$$

This works in the same way as the regular replication except that the number of replications (n) is set at the time of encoding and included in data. Often, within sequences, delayed descriptors are used to specify optional elements using the short delayed descriptor replication factor (031000) that takes a value of either 0 or 1.

Within the csv2bufr module the number of delayed replications needs to be set within the mapping file using the `inputDelayedDescriptorReplicationFactor` key. More information is provided on the mappings page.

## 5.4 Scope of descriptors

BUFR Table B descriptors within classes 0 - 8 contain metadata about the observations. For example, the location of an observations, the instrumentation used to make an observation or the time period over which an observation was made or averaged. These descriptors remain in force and apply to all subsequent elements until they are either reused or set to missing. For example the sequence [007032, 012001, 007032, 012001, 007032] could be used to record air temperature measurements at two different heights, e.g.:

```
# set height of sensor for following observations
[007032] = ["heightOfSensorAboveLocalGroundOrDeckOfMarinePlatform"] = 2.0
[012001] = ["airTemperature"] = 280.15 # air temperature at 2 m height
# redefine height of sensor to 10 m
[007032] = ["heightOfSensorAboveLocalGroundOrDeckOfMarinePlatform"] = 10.0
[012001] = ["airTemperature"] = 280.07 # air temperature at 10 m height
# cancel height of sensor, following observations will have an undefined height
[007032] = ["heightOfSensorAboveLocalGroundOrDeckOfMarinePlatform"] = None
```

## 5.5 Commonly used sequences

Listed below are some commonly used sequences:

- 307080: Sequence for representation of synoptic reports from a fixed land station suitable for SYNOP data.
- 315008: Sequence for the representation of data from moored buoys.
- 315009: Sequence for the representation of data from drifting buoys.
- As this documentation is developed further additional examples will be added.

## 5.6 Further information

The description of the BUFR operators (F = 2 in the FXXYYY notation) is beyond the scope of this documentation. For users wanting to define new sequences, including the use of the operators, it is recommended to refer to Volume I.2 of the WMO Manual on Codes. However, before defining a new sequence it is recommended to check if any of the existing sequence meet the user requirements. See the [support page](#) for information on how to get further information and support..



## BUFR TEMPLATE MAPPING

The mapping between the input CSV data and the output BUFR data is specified in a JSON file. The `csv2bufr` module validates the mapping file against the schema shown at the bottom of this page prior to attempted the transformation to BUFR. This schema specifies 6 primary properties:

- `inputDelayedDescriptorReplicationFactor` - array of integers, values for the delayed descriptor replication factors to use
- `number_header_rows` - integer, the number of header rows in the file before the data rows
- `names_on_row` - integer, which row the column names appear on
- `header` - array of objects (see below), header section containing metadata
- `data` - array of object (see below) section mapping from the CSV columns to the BUFR elements
- `wigos_identifier` - object (see below), section to contain the WIGOS station identifier

Out of these, only the `inputDelayedDescriptorReplicationFactor`, `header` and `data` are mandatory, with the `unexpandedDescriptors` described on the previous page included in the `header` section. Both the `number_header_rows` and `names_on_row` default to one if not specified.

The `header` and `data` sections contain arrays of `bufr_element` objects mapping to either the different fields in the header sections of the BUFR message or to the data section respectively. More information is provided below. In both cases the field `eccodes_key` is used to indicate the BUFR element being mapped to rather than the 6 digit FXXYYY code. For example, the code block below shows how the pressure reduced to mean sea level would be mapped from the column “mslp” in the CSV file to the BUFR element indicated by the `eccodes_key` “`pressureReducedToMeanSeaLevel`” (FXXYYY = 010051).

```
{
  "data": [
    { "eccodes_key": "pressureReducedToMeanSeaLevel", "csv_column": "mslp" }
  ]
}
```

In addition to mapping to the CSV columns, constant values and values from the JSON metadata file can be mapped using the “`value`” and “`jsonpath`” fields. Building on the prior example:

```
{
  "header": [
    { "eccodes_key": "dataCategory", "value": 0 }
  ],
  "data": [
    { "eccodes_key": "latitude", "jsonpath": "$.locations[0].latitude" },
    { "eccodes_key": "longitude", "jsonpath": "$.locations[0].latitude" },
    { "eccodes_key": "pressureReducedToMeanSeaLevel", "csv_column": "mslp" },
  ]
}
```

(continues on next page)

(continued from previous page)

```

    ]
  }

```

Would map: the `dataCategory` field in BUFR section 1 (see *Anatomy of a BUFR4 message*) to the constant value 0; the `latitude` and `longitude` to the elements specified by resolving the `jsonpath` in the metadata file; and the `pressureReducedToMeanSeaLevel` to the data from the “mslp” column in the CSV file.

The keys used for the header elements are listed on the *Anatomy of a BUFR4 message* page, with the mandatory keys highlighted in red. The list of keys can also be found at:

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

Similarly the keys for the different data elements can be found at:

- <https://confluence.ecmwf.int/display/ECC/WMO%3D37+element+table>

## 6.1 inputDelayedDescriptorReplicationFactor

Due to the way that eccodes works any delayed replication factors need to be specified before encoding and included in the mapping file. This currently limits the use of the delayed replication factors to static values for a given mapping. For example every data file that uses a given mapping file has the same optional elements present or the same number of levels in an atmospheric profile present.

For sequences that do not include delayed replications the `inputDelayedDescriptorReplicationFactor` must still be included but may be set to an empty array, e.g.

```

{
  "inputDelayedDescriptorReplicationFactor": []
}

```

## 6.2 bufr\_element

Each item in the `header` and `data` arrays of the mapping template must conform with the definition of the `bufr_element` object specified in the schema shown below. This object contains an `eccodes_key` field specifying the BUFR element the data are being mapped to as described above and up to 3 others pieces of information:

- the source of the data (`value`, `csv_column`, `jsonpath`)
- valid range information (`valid_min`, `valid_max`)
- simple scaling and offset parameters (`scale`, `offset`)

Only one source can be mapped, if multiple sources are specified the validation of the mapping file by `csv2bufr` will fail. The `value` source maps a constant value to the indicated BUFR element. The `csv_column` source maps the indicated column from the CSV file to the indicated BUFR element. The `jsonpath` source maps from the value found by resolving the JSON path in the metadata file to the indicated BUFR element.

The `valid_min` and `valid_max` are optional and can be used to perform a basic quality control of numeric fields. If these fields are specified the `csv2bufr` module checks the value indicated extracted from the source to the indicated valid minimum and maximum values. If outside of the range the value is set to missing.

The `scale` and `offset` fields are conditionally optional, either both can be omitted or both can be included. Including only one will result in a failed validation of the mapping file. These allow simple unit conversions to be performed, for

example from degrees Celsius to Kelvin or from hectopascals to Pascals. The scaled values are calculated as:

$$\text{scaled\_value} = \text{value} \times 10^{\text{scale}} + \text{offset}$$

The scaled value is then used to set the indicated BUFR element. For example:

```
{
  "data": [
    {
      "eccodes_key": "pressureReducedToMeanSeaLevel",
      "csv_column": "mslp",
      "scale": 2,
      "offset": 0
    }
  ]
}
```

Would convert the value contained in the “mslp” column of the CSV file from hPa to Pa by multiplying by 100 and adding 0.

For each of the above elements (value, csv\_column, jsonpath, valid\_min, valid\_max, scale, offset) null values must be excluded from the mapping file.

An individual BUFR descriptor can occur multiple times within a single BUFR message. To allow the indexing of the descriptors within a particular message, and the inclusions of multiple descriptors or keys with the same name, eccodes prepends an index number to the eccodes\_key. For the first occurrence the index number can be omitted but for all other cases it should be included. The index is indicated within the eccodes\_key using #index#eccodes\_key, an example is given below.

```
{
  "data": [
    {
      "#1#eccodes_key": "pressureReducedToMeanSeaLevel",
      "csv_column": "mslp",
      "scale": 2,
      "offset": 0
    }
  ]
}
```

## 6.3 Units

It should be noted that the units of the data to be encoded into BUFR should match those specified in BUFR table B (e.g. see <https://confluence.ecmwf.int/display/ECC/WMO%3D37+element+table>), i.e. Kelvin for temperatures, Pascals for pressure etc. Simple conversions between units are possible as specified above using the scale and offset fields. Some additional examples are given below.

```
{
  "data": [
    {
      "eccodes_key": "airTemperature",
      "csv_column": "AT-fahrenheit",
      "scale": -0.25527,
```

(continues on next page)

(continued from previous page)

```

        "offset": 459.67
    },
    {
        "eccodes_key": "airTemperature",
        "csv_column": "AT-celsius",
        "scale": 0,
        "offset": 273.15
    },
    {
        "eccodes_key": "pressure",
        "csv_column": "pressure-hPa",
        "scale": 2,
        "offset": 0
    }
]
}

```

## 6.4 Schema

```

{
  "$id": "csv2bufr.wis2.0.node.wis",
  "$schema": "https://json-schema.org/draft/2020-12/schema",
  "type": "object",
  "properties": {
    "inputDelayedDescriptorReplicationFactor": {
      "type": "array",
      "items": {"type": "integer"}
    },
    "number_header_rows": {
      "type": "integer",
      "description": "Number of header rows in the file"
    },
    "names_on_row": {
      "type": "integer",
      "description": "Which row the column names appear on"
    },
    "header": {
      "type": "array",
      "items": {"$ref": "#/$defs/bufr_element"},
      "description": "Contents of header sections of BUFR message"
    },
    "data": {
      "type": "array",
      "items": {"$ref": "#/$defs/bufr_element"},
      "description": "mapping from CSV file (or metadata json file) to BUFR"
    },
    "wigos_identifier": {
      "type": "object",
      "description": "Field to contain WIGOS identifier (currently unused)",
      "properties": {

```

(continues on next page)



(continued from previous page)

```

        "csv_column": {"type": "string"},
        "jsonpath": {"type": "string"},
        "value": {"type": "string"}
    },
    "oneOf": [
        {"required": ["value"]},
        {"required": ["csv_column"]},
        {"required": ["jsonpath"]}
    ]
},
"required" : ["inputDelayedDescriptorReplicationFactor","header","data"],
"$defs":{
    "bufr_element": {
        "type": "object",
        "properties": {
            "eccodes_key": {
                "type": "string",
                "description": "eccodes key used to set the value in the BUFR data"
            },
            "value": {
                "type": [
                    "boolean", "object", "array", "number", "string", "integer"
                ],
                "description": "fixed value to use for all data using this mapping"
            },
            "csv_column": {
                "type": "string",
                "description": "column from the CSV file to map to the BUFR element.
↪indicated by eccodes_key"
            },
            "jsonpath": {
                "type": "string",
                "description": "json path to the element in the JSON metadata file"
            },
            "valid_min": {
                "type": "number",
                "description": "Minimum valid value for parameter if set"
            },
            "valid_max": {
                "type": "number",
                "description": "Maximum value for for the parameter if set"
            },
            "scale": {
                "type": "number",
                "description": "Value used to scale the data by before encoding.
↪using the same conventions as in BUFR"
            },
            "offset": {
                "type": "number",
                "description": "Value added to the data before encoding to BUFR.
↪following the same conventions as BUFR"
            }
        }
    }
}

```

(continues on next page)

(continued from previous page)

```
    }
  },
  "required": ["eccodes_key"],
  "allOf": [
    {
      "oneOf": [
        {"required": ["value"]},
        {"required": ["csv_column"]},
        {"required": ["jsonpath"]}
      ]
    },
    {
      "dependentRequired": {"scale": ["offset"]}
    },
    {
      "dependentRequired": {"offset": ["scale"]}
    }
  ]
}
}
```

## EXAMPLES

This page follows through a worked example:

1. Example data file
2. Example metadata file
3. Creating a new mapping file
4. Editing the mapping file
5. Running the transformation

All the example files used are downloadable at the end of this page.

### 7.1 Data file (example-data.csv)

Table 1: example-data.csv

year	month	day	hour	minute	latitude	longitude	slp	mslp	ppp	a	brmh
2022	02	10	6	0	46.2475	6.12774	978.3	1029.90	-0.4	8	412.3

### 7.2 Metadata file (example-metadata.json)

```
{
  "wigosIds": [
    {
      "wid": "0-200000-0-06700"
    }
  ]
}
```

## 7.3 Creating a new mapping file

A command line tool to create an empty BUFR mapping template has been included as part of the csv2bufr module. This can be invoked using the `csv2bufr mappings create <BUFR descriptors>` command. E.g.:

```
csv2bufr mappings create 301150 301011 301012 301021 007031 302001 > bufr-mappings.json
```

generates the following file:

```
{
  "inputDelayedDescriptorReplicationFactor": [],
  "number_header_rows": 1,
  "names_on_row": 1,
  "header": [
    {
      "eccodes_key": "edition",
      "value": null,
      "csv_column": null,
      "jsonpath": null,
      "valid_min": null,
      "valid_max": null,
      "scale": null,
      "offset": null
    },
    {
      "eccodes_key": "masterTableNumber",
      "value": null,
      "csv_column": null,
      "jsonpath": null,
      "valid_min": null,
      "valid_max": null,
      "scale": null,
      "offset": null
    },
    {
      "eccodes_key": "bufrHeaderCentre",
      "value": null,
      "csv_column": null,
      "jsonpath": null,
      "valid_min": null,
      "valid_max": null,
      "scale": null,
      "offset": null
    },
    {
      "eccodes_key": "bufrHeaderSubCentre",
      "value": null,
      "csv_column": null,
      "jsonpath": null,
      "valid_min": null,
      "valid_max": null,
      "scale": null,
      "offset": null
    }
  ]
}
```

(continues on next page)

(continued from previous page)

```

    },
    {
      "eccodes_key": "updateSequenceNumber",
      "value": null,
      "csv_column": null,
      "jsonpath": null,
      "valid_min": null,
      "valid_max": null,
      "scale": null,
      "offset": null
    },
    {
      "eccodes_key": "dataCategory",
      "value": null,
      "csv_column": null,
      "jsonpath": null,
      "valid_min": null,
      "valid_max": null,
      "scale": null,
      "offset": null
    },
    {
      "eccodes_key": "internationalDataSubCategory",
      "value": null,
      "csv_column": null,
      "jsonpath": null,
      "valid_min": null,
      "valid_max": null,
      "scale": null,
      "offset": null
    },
    {
      "eccodes_key": "dataSubCategory",
      "value": null,
      "csv_column": null,
      "jsonpath": null,
      "valid_min": null,
      "valid_max": null,
      "scale": null,
      "offset": null
    },
    {
      "eccodes_key": "masterTablesVersionNumber",
      "value": null,
      "csv_column": null,
      "jsonpath": null,
      "valid_min": null,
      "valid_max": null,
      "scale": null,
      "offset": null
    },
    {

```

(continues on next page)

(continued from previous page)

```
    "eccodes_key": "localTablesVersionNumber",
    "value": null,
    "csv_column": null,
    "jsonpath": null,
    "valid_min": null,
    "valid_max": null,
    "scale": null,
    "offset": null
  },
  {
    "eccodes_key": "typicalYear",
    "value": null,
    "csv_column": null,
    "jsonpath": null,
    "valid_min": null,
    "valid_max": null,
    "scale": null,
    "offset": null
  },
  {
    "eccodes_key": "typicalMonth",
    "value": null,
    "csv_column": null,
    "jsonpath": null,
    "valid_min": null,
    "valid_max": null,
    "scale": null,
    "offset": null
  },
  {
    "eccodes_key": "typicalDay",
    "value": null,
    "csv_column": null,
    "jsonpath": null,
    "valid_min": null,
    "valid_max": null,
    "scale": null,
    "offset": null
  },
  {
    "eccodes_key": "typicalHour",
    "value": null,
    "csv_column": null,
    "jsonpath": null,
    "valid_min": null,
    "valid_max": null,
    "scale": null,
    "offset": null
  },
  {
    "eccodes_key": "typicalMinute",
    "value": null,
```

(continues on next page)

(continued from previous page)

```

        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "typicalSecond",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "typicalDate",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "typicalTime",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "numberOfSubsets",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "observedData",
        "value": null,
        "csv_column": null,
        "jsonpath": null,

```

(continues on next page)

(continued from previous page)

```

        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "compressedData",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "unexpandedDescriptors",
        "value": [
            301150,
            301011,
            301012,
            301021,
            7031,
            302001
        ],
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "subsetNumber",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    }
],
"data": [
    {
        "eccodes_key": "#1#wigosIdentifierSeries",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,

```

(continues on next page)



(continued from previous page)

```

        "offset": null
    },
    {
        "eccodes_key": "#1#wigosIssuerOfIdentifier",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "#1#wigosIssueNumber",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "#1#wigosLocalIdentifierCharacter",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "#1#year",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "#1#month",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    },

```

(continues on next page)

(continued from previous page)

```

{
    "eccodes_key": "#1#day",
    "value": null,
    "csv_column": null,
    "jsonpath": null,
    "valid_min": null,
    "valid_max": null,
    "scale": null,
    "offset": null
},
{
    "eccodes_key": "#1#hour",
    "value": null,
    "csv_column": null,
    "jsonpath": null,
    "valid_min": null,
    "valid_max": null,
    "scale": null,
    "offset": null
},
{
    "eccodes_key": "#1#minute",
    "value": null,
    "csv_column": null,
    "jsonpath": null,
    "valid_min": null,
    "valid_max": null,
    "scale": null,
    "offset": null
},
{
    "eccodes_key": "#1#latitude",
    "value": null,
    "csv_column": null,
    "jsonpath": null,
    "valid_min": null,
    "valid_max": null,
    "scale": null,
    "offset": null
},
{
    "eccodes_key": "#1#longitude",
    "value": null,
    "csv_column": null,
    "jsonpath": null,
    "valid_min": null,
    "valid_max": null,
    "scale": null,
    "offset": null
},
{
    "eccodes_key": "#1#heightOfBarometerAboveMeanSeaLevel",

```

(continues on next page)

(continued from previous page)

```

        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "#1#nonCoordinatePressure",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "#1#pressureReducedToMeanSeaLevel",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "#1#3HourPressureChange",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    },
    {
        "eccodes_key": "#1#characteristicOfPressureTendency",
        "value": null,
        "csv_column": null,
        "jsonpath": null,
        "valid_min": null,
        "valid_max": null,
        "scale": null,
        "offset": null
    }
],
"wigos_identifier": {
    "value": null,
    "jsonpath": null,

```

(continues on next page)

(continued from previous page)

```
    "csv_column": null
  }
}
```

## 7.4 Customising the mapping file (bufr-mappings-edited.json)

Editing the bufr mappings file to map to the above example CSV data we have:

```
{
  "inputDelayedDescriptorReplicationFactor": [],
  "number_header_rows": 1,
  "names_on_row": 1,
  "header": [
    {
      "eccodes_key": "edition",
      "value": 4
    },
    {
      "eccodes_key": "masterTableNumber",
      "value": 0
    },
    {
      "eccodes_key": "updateSequenceNumber",
      "value": 0
    },
    {
      "eccodes_key": "dataCategory",
      "value": 0
    },
    {
      "eccodes_key": "internationalDataSubCategory",
      "value": 6
    },
    {
      "eccodes_key": "masterTablesVersionNumber",
      "value": 36
    },
    {
      "eccodes_key": "typicalYear",
      "csv_column": "year"
    },
    {
      "eccodes_key": "typicalMonth",
      "csv_column": "month"
    },
    {
      "eccodes_key": "typicalDay",
      "csv_column": "day"
    }
  ]
}
```

(continues on next page)

(continued from previous page)

```

        "eccodes_key": "typicalHour",
        "csv_column": "hour"
    },
    {
        "eccodes_key": "typicalMinute",
        "csv_column": "minute"
    },
    {
        "eccodes_key": "numberOfSubsets",
        "value": 1
    },
    {
        "eccodes_key": "observedData",
        "value": 1
    },
    {
        "eccodes_key": "compressedData",
        "value": 0
    },
    {
        "eccodes_key": "unexpandedDescriptors",
        "value": [
            301150,
            301011,
            301012,
            301021,
            7031,
            302001
        ]
    }
],
"data": [
    {
        "eccodes_key": "#1#wigosIdentifierSeries",
        "jsonpath": "$.wigosIds[0].wid_series"
    },
    {
        "eccodes_key": "#1#wigosIssuerOfIdentifier",
        "jsonpath": "$.wigosIds[0].wid_issuer"
    },
    {
        "eccodes_key": "#1#wigosIssueNumber",
        "jsonpath": "$.wigosIds[0].wid_issue_number"
    },
    {
        "eccodes_key": "#1#wigosLocalIdentifierCharacter",
        "jsonpath": "$.wigosIds[0].wid_local"
    },
    {
        "eccodes_key": "#1#year",
        "csv_column": "year"
    },
],

```

(continues on next page)

(continued from previous page)

```
{
  {
    "eccodes_key": "#1#month",
    "csv_column": "month"
  },
  {
    "eccodes_key": "#1#day",
    "csv_column": "day"
  },
  {
    "eccodes_key": "#1#hour",
    "csv_column": "hour"
  },
  {
    "eccodes_key": "#1#minute",
    "csv_column": "minute"
  },
  {
    "eccodes_key": "#1#latitude",
    "csv_column": "latitude"
  },
  {
    "eccodes_key": "#1#longitude",
    "csv_column": "longitude"
  },
  {
    "eccodes_key": "#1#heightOfBarometerAboveMeanSeaLevel",
    "csv_column": "brmh"
  },
  {
    "eccodes_key": "#1#nonCoordinatePressure",
    "csv_column": "slp",
    "scale": 2,
    "offset": 0
  },
  {
    "eccodes_key": "#1#pressureReducedToMeanSeaLevel",
    "csv_column": "mslp",
    "scale": 2,
    "offset": 0
  },
  {
    "eccodes_key": "#1#3HourPressureChange",
    "csv_column": "ppp",
    "scale": 2,
    "offset": 0
  },
  {
    "eccodes_key": "#1#characteristicOfPressureTendency",
    "csv_column": "a"
  }
}
]
```

Note that the sequence includes no delayed replications and so the `inputDelayedDescriptorReplicationFactor` can be left as an empty array. Elements that would be set to null have been removed.

## 7.5 Transformation

```
csv2bufr data transform ./example-data.csv --bufr-template ./bufr-mappings-edited.json \  
--station-metadata ./example-metadata.json --output-dir ./
```

The links below can be used to download the example files:

- [example-data.csv](#)
- [bufr-mappings-edited.json](#)
- [example-metadata.json](#)
- [example output \(d0464c97a88ea99f119e87629844c5dd.bufr4\)](#)





## DEVELOPMENT

See discussion board and issues on GitHub:

- [Discussion board](#)
- [Issues](#)



## SUPPORT

See discussion board and issues on GitHub:

- [Discussion board](#)
- [Issues](#)



## LICENSE

### 10.1 Software

Apache License  
Version 2.0, January 2004  
<http://www.apache.org/licenses/>

#### TERMS AND CONDITIONS FOR USE, REPRODUCTION, AND DISTRIBUTION

##### 1. Definitions.

"License" shall mean the terms and conditions for use, reproduction, and distribution as defined by Sections 1 through 9 of this document.

"Licensor" shall mean the copyright owner or entity authorized by the copyright owner that is granting the License.

"Legal Entity" shall mean the union of the acting entity and all other entities that control, are controlled by, or are under common control with that entity. For the purposes of this definition, "control" means (i) the power, direct or indirect, to cause the direction or management of such entity, whether by contract or otherwise, or (ii) ownership of fifty percent (50%) or more of the outstanding shares, or (iii) beneficial ownership of such entity.

"You" (or "Your") shall mean an individual or Legal Entity exercising permissions granted by this License.

"Source" form shall mean the preferred form for making modifications, including but not limited to software source code, documentation source, and configuration files.

"Object" form shall mean any form resulting from mechanical transformation or translation of a Source form, including but not limited to compiled object code, generated documentation, and conversions to other media types.

"Work" shall mean the work of authorship, whether in Source or Object form, made available under the License, as indicated by a

(continues on next page)

(continued from previous page)

copyright notice that is included in or attached to the work (an example is provided in the Appendix below).

"Derivative Works" shall mean any work, whether in Source or Object form, that is based on (or derived from) the Work and for which the editorial revisions, annotations, elaborations, or other modifications represent, as a whole, an original work of authorship. For the purposes of this License, Derivative Works shall not include works that remain separable from, or merely link (or bind by name) to the interfaces of, the Work and Derivative Works thereof.

"Contribution" shall mean any work of authorship, including the original version of the Work and any modifications or additions to that Work or Derivative Works thereof, that is intentionally submitted to Licensor for inclusion in the Work by the copyright owner or by an individual or Legal Entity authorized to submit on behalf of the copyright owner. For the purposes of this definition, "submitted" means any form of electronic, verbal, or written communication sent to the Licensor or its representatives, including but not limited to communication on electronic mailing lists, source code control systems, and issue tracking systems that are managed by, or on behalf of, the Licensor for the purpose of discussing and improving the Work, but excluding communication that is conspicuously marked or otherwise designated in writing by the copyright owner as "Not a Contribution."

"Contributor" shall mean Licensor and any individual or Legal Entity on behalf of whom a Contribution has been received by Licensor and subsequently incorporated within the Work.

2. Grant of Copyright License. Subject to the terms and conditions of this License, each Contributor hereby grants to You a perpetual, worldwide, non-exclusive, no-charge, royalty-free, irrevocable copyright license to reproduce, prepare Derivative Works of, publicly display, publicly perform, sublicense, and distribute the Work and such Derivative Works in Source or Object form.
3. Grant of Patent License. Subject to the terms and conditions of this License, each Contributor hereby grants to You a perpetual, worldwide, non-exclusive, no-charge, royalty-free, irrevocable (except as stated in this section) patent license to make, have made, use, offer to sell, sell, import, and otherwise transfer the Work, where such license applies only to those patent claims licensable by such Contributor that are necessarily infringed by their Contribution(s) alone or by combination of their Contribution(s) with the Work to which such Contribution(s) was submitted. If You institute patent litigation against any entity (including a cross-claim or counterclaim in a lawsuit) alleging that the Work or a Contribution incorporated within the Work constitutes direct or contributory patent infringement, then any patent licenses granted to You under this License for that Work shall terminate as of the date such litigation is filed.

(continues on next page)

(continued from previous page)

4. Redistribution. You may reproduce and distribute copies of the Work or Derivative Works thereof in any medium, with or without modifications, and in Source or Object form, provided that You meet the following conditions:
- (a) You must give any other recipients of the Work or Derivative Works a copy of this License; and
  - (b) You must cause any modified files to carry prominent notices stating that You changed the files; and
  - (c) You must retain, in the Source form of any Derivative Works that You distribute, all copyright, patent, trademark, and attribution notices from the Source form of the Work, excluding those notices that do not pertain to any part of the Derivative Works; and
  - (d) If the Work includes a "NOTICE" text file as part of its distribution, then any Derivative Works that You distribute must include a readable copy of the attribution notices contained within such NOTICE file, excluding those notices that do not pertain to any part of the Derivative Works, in at least one of the following places: within a NOTICE text file distributed as part of the Derivative Works; within the Source form or documentation, if provided along with the Derivative Works; or, within a display generated by the Derivative Works, if and wherever such third-party notices normally appear. The contents of the NOTICE file are for informational purposes only and do not modify the License. You may add Your own attribution notices within Derivative Works that You distribute, alongside or as an addendum to the NOTICE text from the Work, provided that such additional attribution notices cannot be construed as modifying the License.

You may add Your own copyright statement to Your modifications and may provide additional or different license terms and conditions for use, reproduction, or distribution of Your modifications, or for any such Derivative Works as a whole, provided Your use, reproduction, and distribution of the Work otherwise complies with the conditions stated in this License.

5. Submission of Contributions. Unless You explicitly state otherwise, any Contribution intentionally submitted for inclusion in the Work by You to the Licensor shall be under the terms and conditions of this License, without any additional terms or conditions. Notwithstanding the above, nothing herein shall supersede or modify the terms of any separate license agreement you may have executed with Licensor regarding such Contributions.
6. Trademarks. This License does not grant permission to use the trade names, trademarks, service marks, or product names of the Licensor, except as required for reasonable and customary use in describing the

(continues on next page)

(continued from previous page)

origin of the Work and reproducing the content of the NOTICE file.

7. Disclaimer of Warranty. Unless required by applicable law or agreed to in writing, Licensor provides the Work (and each Contributor provides its Contributions) on an "AS IS" BASIS, WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied, including, without limitation, any warranties or conditions of TITLE, NON-INFRINGEMENT, MERCHANTABILITY, or FITNESS FOR A PARTICULAR PURPOSE. You are solely responsible for determining the appropriateness of using or redistributing the Work and assume any risks associated with Your exercise of permissions under this License.
8. Limitation of Liability. In no event and under no legal theory, whether in tort (including negligence), contract, or otherwise, unless required by applicable law (such as deliberate and grossly negligent acts) or agreed to in writing, shall any Contributor be liable to You for damages, including any direct, indirect, special, incidental, or consequential damages of any character arising as a result of this License or out of the use or inability to use the Work (including but not limited to damages for loss of goodwill, work stoppage, computer failure or malfunction, or any and all other commercial damages or losses), even if such Contributor has been advised of the possibility of such damages.
9. Accepting Warranty or Additional Liability. While redistributing the Work or Derivative Works thereof, You may choose to offer, and charge a fee for, acceptance of support, warranty, indemnity, or other liability obligations and/or rights consistent with this License. However, in accepting such obligations, You may act only on Your own behalf and on Your sole responsibility, not on behalf of any other Contributor, and only if You agree to indemnify, defend, and hold each Contributor harmless for any liability incurred by, or claims asserted against, such Contributor by reason of your accepting any such warranty or additional liability.

END OF TERMS AND CONDITIONS

APPENDIX: How to apply the Apache License to your work.

To apply the Apache License to your work, attach the following boilerplate notice, with the fields enclosed by brackets "[]" replaced with your own identifying information. (Don't include the brackets!) The text should be enclosed in the appropriate comment syntax for the file format. We also recommend that a file or class name and description of purpose be included on the same "printed page" as the copyright notice for easier identification within third-party archives.

Copyright 2021-2022, World Meteorological Organization (WMO)

Licensed under the Apache License, Version 2.0 (the "License");  
you may not use this file except in compliance with the License.

(continues on next page)



(continued from previous page)

You may obtain a copy of the License at

<http://www.apache.org/licenses/LICENSE-2.0>

Unless required by applicable law or agreed to in writing, software distributed under the License is distributed on an "AS IS" BASIS, WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied. See the License for the specific language governing permissions and limitations under the License.

## 10.2 Documentation

The documentation is released under the [Creative Commons Attribution 4.0 International \(CC BY 4.0\)](#) license.



## INDICES AND TABLES

- `genindex`
- `modindex`
- `search`