GRIB decoding with ecCodes

Introduction to ECMWF computing services

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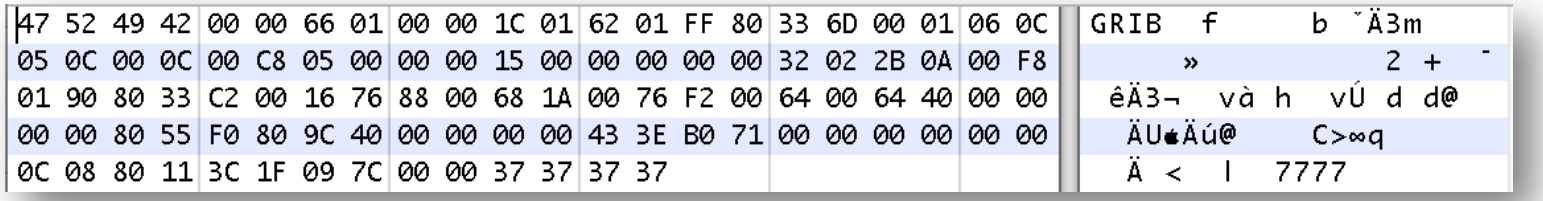
What is GRIB ?

- GRIB – “**G**eneral **R**egularly-distributed **I**nformation in **B**inary form”
  - Code defined by the WMO / CBS in 1985 for the exchange of large volumes of gridded data
  - Machine independent
  - Requires software for encoding and decoding



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

33	6D	00	01	06	0C										
32	02	2B	0A	00	F8										
64	00	64	40	00	00										
00	00	00	00	00	00										

GRIB f b ˇÄ3m
» 2 + -
êÄ3¬ và h vÚ d d@
ÄU◆Äú@ C>∞q
Ä < | 7777

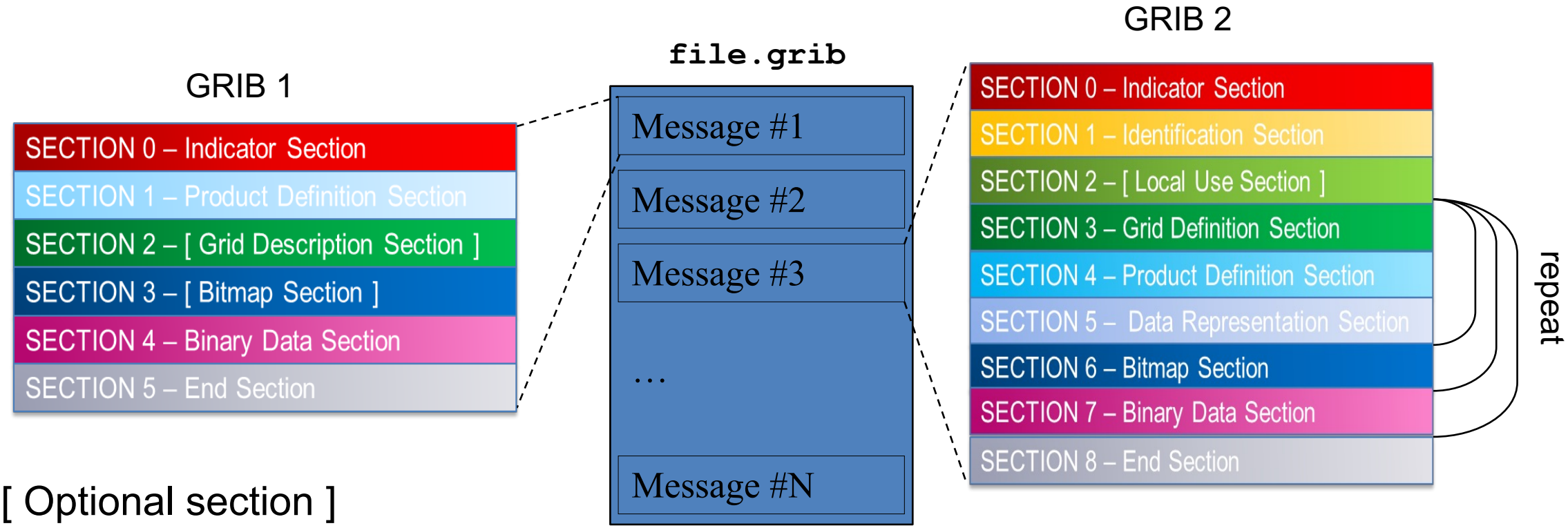
- Currently there are two different coding standards
  - GRIB edition 1
    - Used currently for ECMWF operational pressure level and (most) surface level data
  - GRIB edition 2
    - Used for ECMWF operational model level data since 11 May 2011 and some new surface data
- ECMWF plans to migrate fully to GRIB edition 2 by 2026 !

GRIB structure

- A file may contain one or more GRIB messages
- Each message contains several sections
- A file can contain a mix of editions 1 and 2

```
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
```

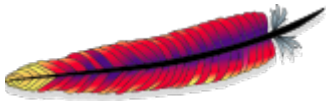
```
GRIB  f     b ˜Ä3m
    »           2 +  ˜
 êÄ3¬  và h  vÚ d d@
 ÄU◖ÄÚú@    C>∞q
 Ä <  |  7777
```



[Optional section]

What is ecCodes ?

- ecCodes is a package developed by ECMWF for decoding and encoding messages in the following formats:
  - WMO FM-92 GRIB edition 1 and edition 2 (and edition 3)
  - WMO FM-94 BUFR edition 3 and edition 4
  - WMO GTS abbreviated header
- The package includes:
  - command line tools (the GRIB and BUFR Tools) to provide a quick and easy way to manipulate data
  - C, Python and Fortran 90 APIs
- Provides an easy and reliable way of encoding and decoding
  - GRIB 1 and GRIB 2 (and GRIB 3) messages using the **SAME** function calls
- Released under the Apache 2.0 license

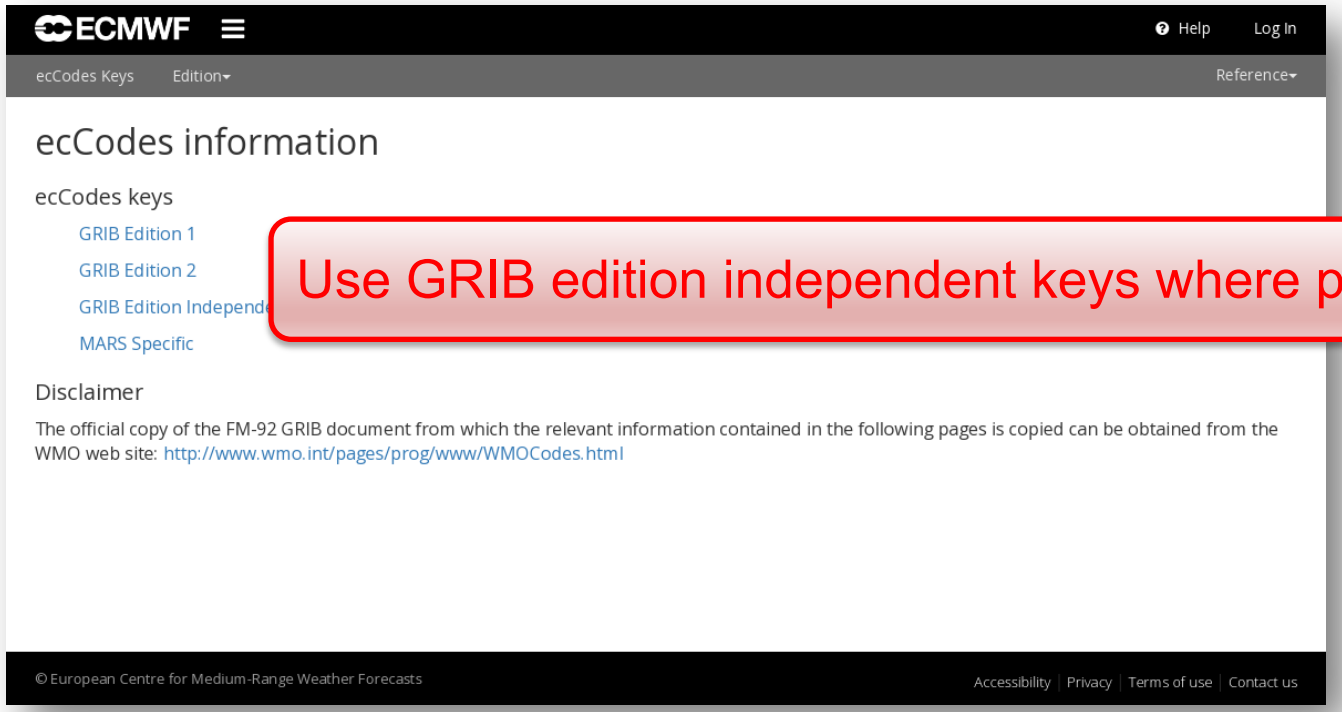


- Available on GitHub

ecCodes key / value based approach

- ecCodes uses a key/value based approach to access information in a GRIB message
  - numberOfPointsAlongAParallel => Number of points along a parallel
  - numberOfPointsAlongAMeridian => Number of points along a meridian
  - …

https://codes.ecmwf.int/grib/



Use GRIB edition independent keys where possible !

ecCodes keys – parameter

- The definition of the parameter is very different in the two GRIB editions

GRIB 1 keys	GRIB 2 keys
centre	discipline
table2Version	parameterCategory
indicatorOfParameter	parameterNumber
levelType	typeOfFirstFixedSurface
level	scaleFactorOfFirstFixedSurface
…	scaledValueOfFirstFixedSurface
	typeOfSecondFixedSurface
	scaleFactorOfSecondFixedSurface
	scaledValueOfSecondFixedSurface
	…

ecCodes keys – parameter namespace

- ecCodes provides some edition-independent keys to identify a parameter

Key name	Example value
paramId	151
shortName	msl
centre	ecmf (or 98)
name	Mean sea level pressure
unit	Pa

- This set of keys is the parameter ***namespace***
- ecCodes provides a number of additional namespaces:
  - ‘parameter’, ‘time’, ‘geography’, ‘vertical’, ‘statistics’, ‘mars’

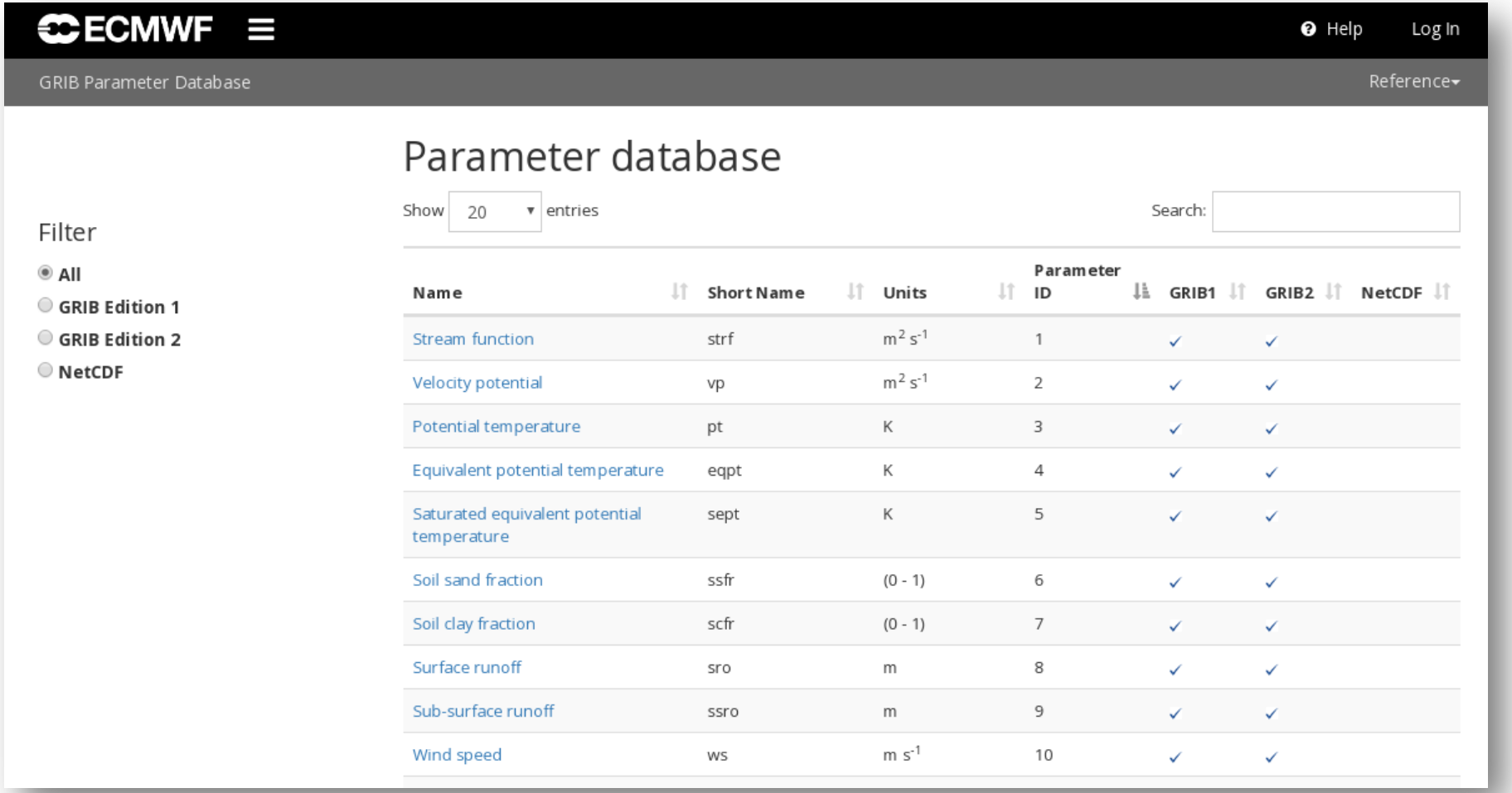
ecCodes – using GRIB edition-independent keys

```
...

edition = codes_get(gid,"edition")

if edition == 1:

  paramNum = codes_get(gid,"indicatorOfparameter")

  table = codes_get(gid,"table2Version")

elif edition == 2:

  paramNum = codes_get(gid,"parameterNumber")

  category = codes_get(gid,"parameterCategory")

...
```

```
...

shortName = codes_get(gid,"shortName")

paramId = codes_get(gid,"paramId")

units = codes_get(gid,"units")

...
```

GRIB parameters – the Parameter Database

https://codes.ecmwf.int/grib/param-db/

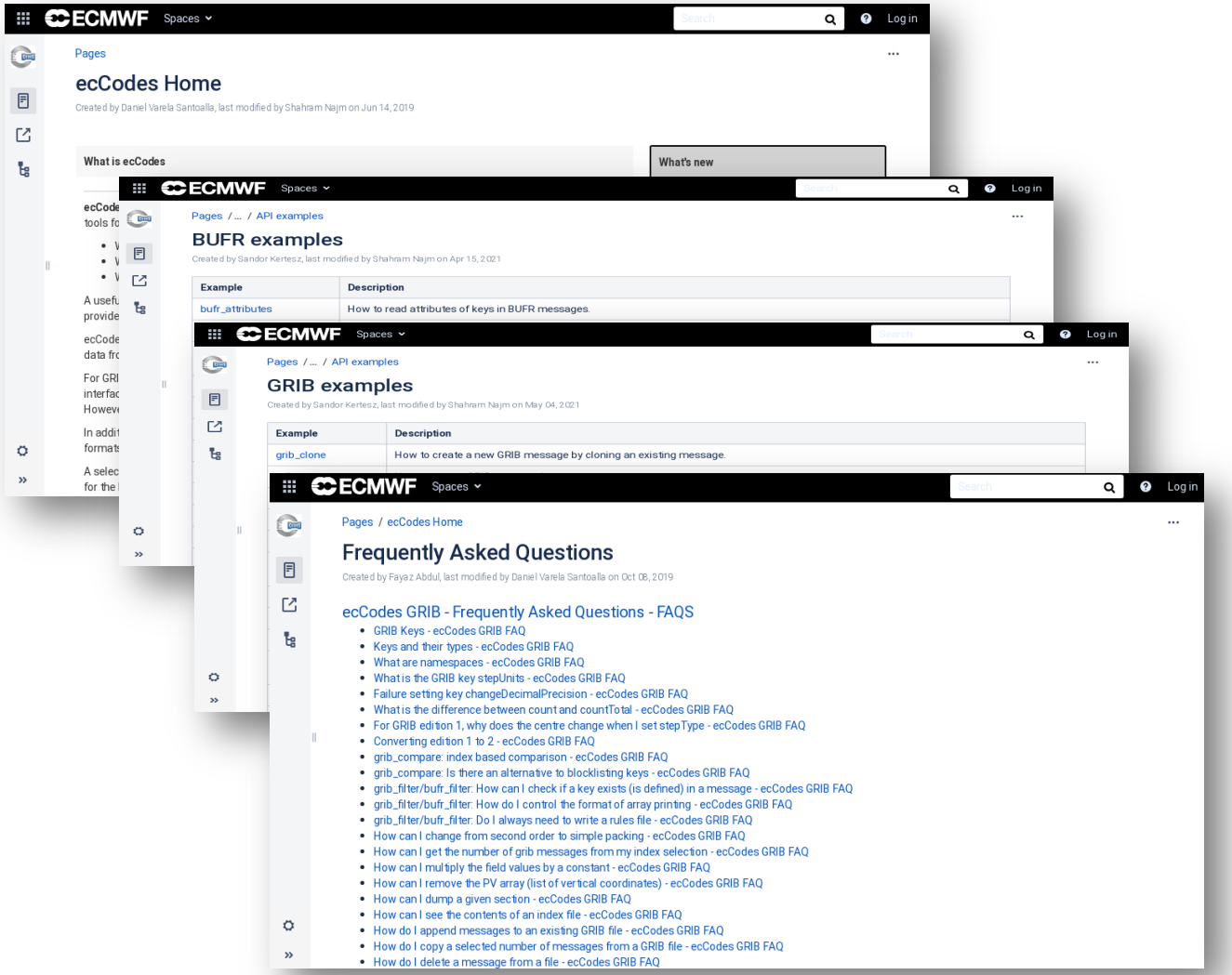


ecCodes documentation

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

- GRIB and BUFR API examples
  - C
  - Python
  - Fortran 90
  - Command-line tools
- FAQs

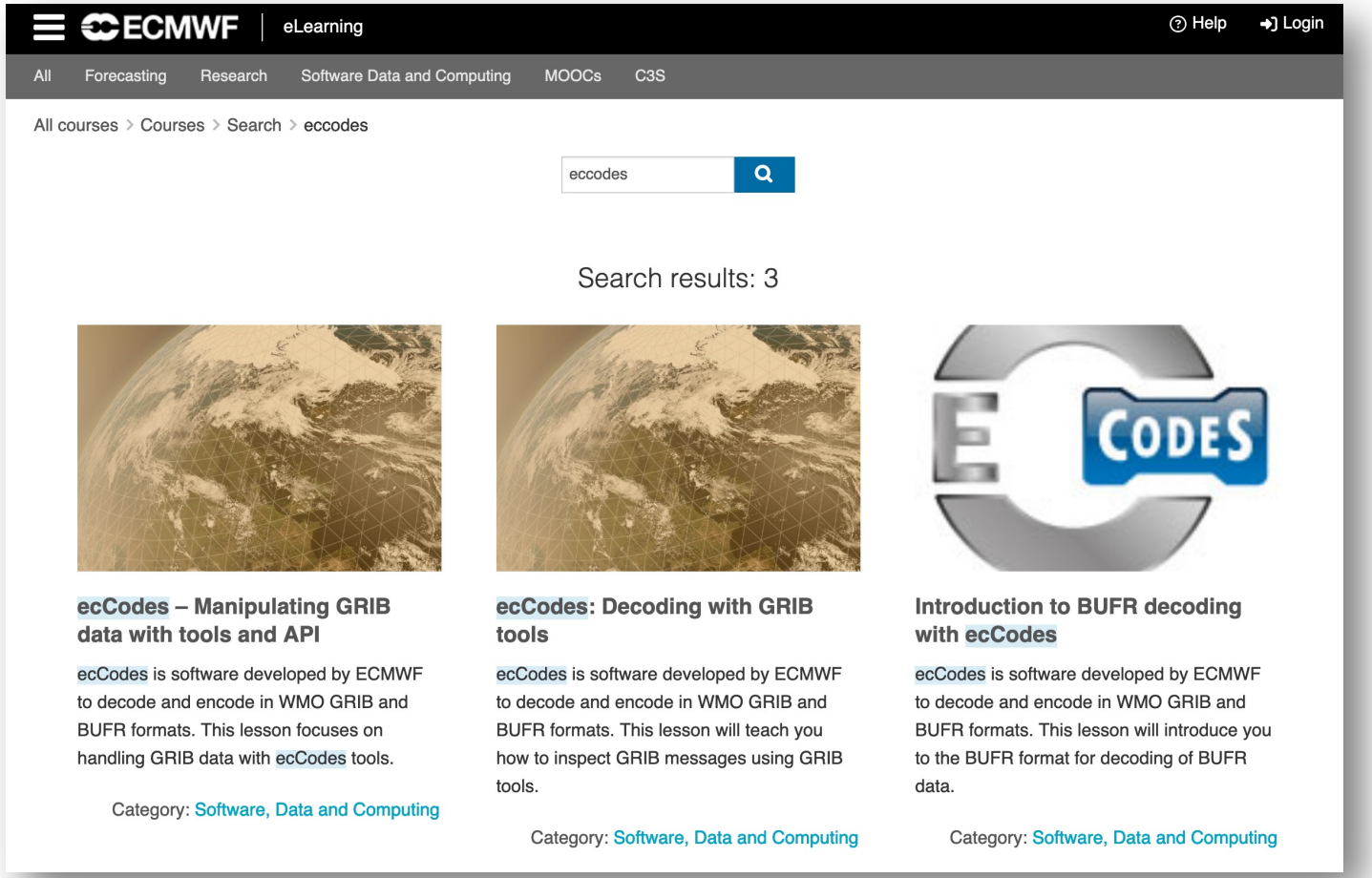
Python3 only



ecCodes eLearning resources

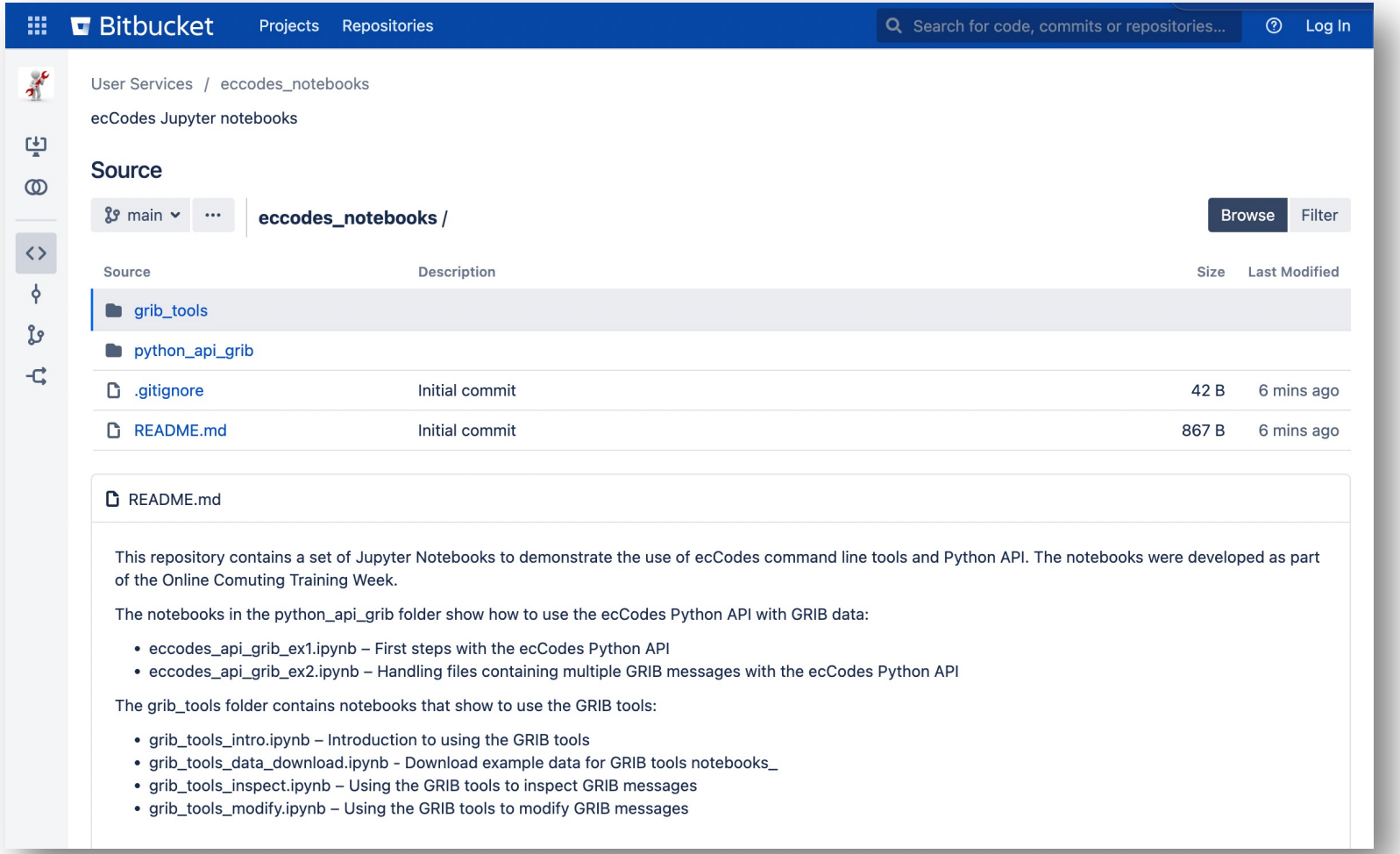
https://www.ecmwf.int/en/learning/education-material/elearning-online-resources

- ecCodes: Decoding with GRIB tools
- ecCodes: Manipulating GRIB data with tools and API



ecCodes Jupyter Notebooks

https://git.ecmwf.int/projects/USS/repos/eccodes_notebooks/browse



Questions ?

GRIB Tools

- All of the tools use a common syntax

```
grib_<tool> [options] grib_file grib_file … [output_grib]
```

- There is tools for getting information about the ecCodes installation
  - codes_info
- There are tools to inspect the content of GRIB messages
  - grib_ls grib_dump grib_get grib_get_data
- There are tools for counting and copying some messages
  - grib_count, grib_copy codes_split_file
- There is a tool for comparing GRIB messages
  - grib_compare
- There are tools for making changes to the content of a GRIB message and converting from GRIB to NetCDF
  - grib_set, grib_filter, grib_to_netcdf

GRIB Tools – getting help

- UNIX ‘man’-style pages are available for each tool by running the tool without any options or input file

```
$ grib_dump
NAME    grib_dump

DESCRIPTION
        Dump the content of a grib file in different formats.

USAGE
        grib_dump [options] grib_file grib_file ...

OPTIONS
        -O      Octet mode. WMO documentation style dump.
        -D      Debug mode.
        -d      Print all data values.
...
```

grib_ls – list the content of GRIB files

- Use grib_ls to get a summary of the content of GRIB files

- Main options

`-p key1,key2,…`	Keys to print
`-P key1,key2,…`	Additional keys to print
`-w key1=val1,key2!=val2…`	Where option
`-B "key asc, key desc"`	Order by: “step asc, centre desc”
`-n namespace`	Print keys for `namespace`
`-m`	Print MARS keys
`-j`	JSON output
`-l lat,lon[,MODE,FILE]`	Value(s) nearest to lat-lon point
`-F format`	Format for floating point values
`-s key1=val1,key2=val2`	Key values to set for output

grib_ls – examples

- Use `-p` option to specify a list of keys to be printed

```
$ grib_ls file.grib1
file.grib1
edition  centre  typeOfLevel  level   dataDate ... dataType  shortName packingType  gridType
1        ecmf    isobaricInhPa  1000  20231022 ...  an        t         spectral_complex  sh
1        ecmf    isobaricInhPa  500   20231022 ...  an        t         spectral_complex  sh
1        ecmf    isobaricInhPa  200   20231022 ...  an        t         spectral_complex  sh
1        ecmf    isobaricInhPa  100   20231922 ...  an        t         spectral_complex  sh
4 of 4 grib messages in file.grib1

4 of 4 total grib messages in 1 files
```

```
$ grib_ls -p centre,dataDate,shortName,paramId,typeOfLevel,level file.grib1
file.grib1
centre      dataDate    shortName   paramId         typeOfLevel       level
ecmf          20231022    t           130       isobaricInhPa     1000
ecmf          20231022    t           130       isobaricInhPa     500
ecmf          20231022    t           130       isobaricInhPa     200
ecmf          20231022    t           130       isobaricInhPa     100
4 of 4 grib messages in file.grib1

4 of 4 total grib messages in 1 files
```

grib_ls – examples

- When a key is not present in the GRIB file, it returns “not found” for this key

```
$ grib_ls -p my_key  file.grib1
file.grib1
my_key
not_found

$ echo $?
0
```

exit code returned = 0

- If you need the command to fail, use the grib_get tool
  - grib_ls is more for interactive use
  - use grib_get within scripts

Using the ‘where’ option

- The where option `-w` can be used with all the GRIB Tools
- Constraints are of the form key=value or key!=value or key=value1/value2/value2

```
-w key1=value1,key2:i!=value2,key3:s=value3
```

- Messages are processed only if they match ALL the key / value constraints

```
$ grib_ls -w level=100 file.grib1                    “IS”
...
$ grib_ls -w level!=100 file.grib1                   “NOT”
...
$ grib_ls -w level=100,stepRange=3 file.grib1        “AND”
...
$ grib_ls -w level=100/200/300/500 file.grib1        “OR”
...
```

Specifying the type of the key

- All ecCodes keys have a default type
  - e.g. string, integer, floating point
- The type of the key can be specified as follows:
  - `key` → native type
  - `key:i` → integer
  - `key:s` → string
  - `key:d` → double

```
$ grib_ls -p centre:i,dataDate,shortName,paramId,typeOfLevel,level file.grib1
file.grib1
centre      dataDate    shortName   paramId         typeOfLevel       level
98          20231022    t           130         isobaricInhPa     1000
98          20231022    t           130         isobaricInhPa     500
98          20231022    t           130         isobaricInhPa     200
98          20231022    t           130         isobaricInhPa     100
4 of 4 grib messages in file.grib1

4 of 4 total grib messages in 1 files
```

grib_ls – stepRange and stepUnits

- The step is always printed as an integer value
- By default the units of the step are printed in hours
- To obtain the step in other units set the stepUnits key appropriately with the `-s` option

```
$ grib_ls -p stepRange f1.grib1
f1.grib1
stepRange
6
12
...
$ grib_ls -s stepUnits=m -p stepRange f1.grib1
f1.grib1
stepRange
360
720
```

stepUnits can be s, m, h, 3h, 6h, 12h, D, M, Y, 10Y, 30Y, C

Finding nearest grid points with grib_ls

- The value of a GRIB field close to a specified Latitude/Longitude point can be found with grib_ls

optional

```
grib_ls -l Latitude,Longitude,MODE,file grib_file
```

`MODE` Can take the values

4	Print values at the 4 nearest grid points (default)
1	Print value at the closest grid point

`file` Specifies a GRIB file to use as a mask
The closest *land* point (with mask ≥ 0.5) is printed

- GRIB files specified must contain grid point data

grib_dump – dump contents of GRIB files

- Use grib_dump to get a detailed view of the content of a file containing one or more GRIB messages

- Main options:

`-O`	Octet mode (WMO Documentation style)
`-D`	Debug mode
`-a`	Print key alias information
`-t`	Print key type information
`-H`	Print octet content in hexadecimal
`-w key{=/!=}value,…`	Where option
`-j`	JSON mode

`...`

grib_dump – examples

```
$ grib_dump file.grib1
***** FILE: file.grib1
#==============   MESSAGE 1 ( length=4284072 )             ==============
GRIB {
  editionNumber = 1;
  table2Version = 128;
  # European Center for Medium-Range Weather Forecasts (grib1/0.table)
  centre = 98;
  generatingProcessIdentifier = 141;
  # Geopotential  (m**2 s**-2)  (grib1/2.98.128.table)
  indicatorOfParameter = 129;
  # Surface  (of the Earth, which includes sea surface)  (grib1/3.table)
  indicatorOfTypeOfLevel = 1;
  level = 0;
  # Forecast product valid at reference time + P1  (P1>0)  (grib1/5.table)
  timeRangeIndicator = 0;
  # Unknown code table entry (grib1/0.ecmf.table)
  subCentre = 0;
  paramId = 129;
  #-READ ONLY- units = m**2 s**-2;
  #-READ ONLY- nameECMF = Geopotential;
  #-READ ONLY- name = Geopotential;
  decimalScaleFactor = 0;
  dataDate = 20231022;
  dataTime = 0; ...
```

Some keys are read only

keys are case sensitive:

dataDate, dataTime

grib_dump examples: WMO octet mode

```
$ grib_dump -O file.grib1
***** FILE: file.grib1
==============   MESSAGE 1 ( length=4284072 )             ==============
1-4   identifier = GRIB
5-7   totalLength = 4284072
8     editionNumber = 1
====================== SECTION_1 ( length=52, padding=0 ) ======================
1-3   section1Length = 52
4     table2Version = 128
5     centre = 98 [European Center for Medium-Range Weather Forecasts (grib1/0.table) ]
6     generatingProcessIdentifier = 141
7     gridDefinition = 255
8     section1Flags = 128 [10000000]
9     indicatorOfParameter = 129 [Geopotential  (m**2 s**-2) (grib1/2.98.128.table) ]
10    indicatorOfTypeOfLevel = 1 [Surface  (of the Earth, which includes sea surface)  (grib1/3.table) ]
11-12 level = 0
13    yearOfCentury = 23
14    month = 10
15    day = 22
16    hour = 0
17    minute = 0
18    unitOfTimeRange = 1 [Hour (grib1/4.table) ]
...
```

grib_dump examples: Octet mode with types, aliases and Hex

```
$ grib_dump -OtaH  file.grib1
***** FILE: file.grib1
==============   MESSAGE 1 ( length=4284072 )             ==============
1-4    ascii identifier = GRIB ( 0x47 0x52 0x49 0x42 )
5-7    g1_message_length totalLength = 4284072 ( 0x41 0x5E 0xA8 )
8      unsigned editionNumber = 1 ( 0x01 ) [ls.edition]
====================== SECTION_1 ( length=52, padding=0 ) ======================
1-3    section_length section1Length = 52 ( 0x00 0x00 0x34 )
4      unsigned table2Version = 128 ( 0x80 ) [gribTablesVersionNo]
5      codetable centre = 98 ( 0x62 ) [European Center for Medium-Range Weather Forecasts(grib1/0.table) ]
                    [identificationOfOriginatingGeneratingCentre,originatingCentre, ls.centre,
centreForTable2]
6      unsigned generatingProcessIdentifier = 141 ( 0x88 ) [generatingProcessIdentificationNumber, process]
7      unsigned gridDefinition = 255 ( 0xFF )
8      codeflag section1Flags = 128 [10000000] ( 0x80 )
9      codetable indicatorOfParameter = 129 ( 0x81 ) [Geopotential (m**2 s**-2)(grib1/2.98.128.table) ]
10     codetable indicatorOfTypeOfLevel = 1 ( 0x01 ) [Surface  (of the Earth,which includes sea surface)
    (grib1/3.table) ] [levelType, mars.levtype]
11-12  unsigned level = 0 ( 0x00 0x00 ) [vertical.topLevel vertical.bottomLevel, ls.level, lev]
13     unsigned yearOfCentury = 23 ( 0x17 )
14     unsigned month = 10 ( 0x0A )
15     unsigned day = 22 ( 0x16 )
16     unsigned hour = 0 ( 0x00 )
...
```

grib_get_data – print data values

- Use grib_get_data to print a list of latitude, longitude (for grid point data) and data values from one or more GRIB files
- C-style format of output using the `-F` option
  - `-F "%.4f"` – Decimal format with 4 decimal places (1.2345)
  - `-F "%.4e"` – Exponent format with 4 decimal places (1.2345E-03)

Usage

`-p key1,key2,…`	Keys to print
`-w key1=val1,key2!=val2,…`	Where option
`-m missingValue`	Specify missing value string
`-F / -L format`	C-style format for output values / lat-lon
`-f`	Do *not* fail on error (fails on error by default)
`-V`	Print ecCodes Version

Missing data values are not printed by default

`...`

grib_get_data – example

```
$ grib_get_data -F "%.4f" f1.grib1
Latitude Longitude Value
   81.000    0.000 22.5957
   81.000    1.500 22.9009
   81.000    3.000 22.8359
   81.000    4.500 22.3379
   81.000    6.000 21.5547
   81.000    7.500 20.7344
   81.000    9.000 19.8916
   81.000   10.500 18.5747
   81.000   12.000 17.2578
   81.000   13.500 16.1343
   81.000   15.000 14.9785
   81.000   16.500 13.8296
...
```

Format -F option applies to values only - not to the Latitudes and Longitudes

grib_get_data – format latitude and longitudes

```
$ grib_get_data -L"%9.6f %9.6f" -F "%.4f" f1.grib1
Latitude Longitude Value
 81.000000  0.000000 22.5957
 81.000000  1.500000 22.9009
 81.000000  3.000000 22.8359
 81.000000  4.500000 22.3379
 81.000000  6.000000 21.5547
 81.000000  7.500000 20.7344
 81.000000  9.000000 19.8916
 81.000000 10.500000 18.5747
 81.000000 12.000000 17.2578
 81.000000 13.500000 16.1343
 81.000000 15.000000 14.9785
 81.000000 16.500000 13.8296
...
```

grib_get_data – missing values example

- Missing values are not printed by default

```
> grib_get_data -m XXXXX -F "%.4f" f1.grib1
Latitude Longitude Value
...
   81.000    90.000 9.4189
   81.000    91.500 8.6782
   81.000    93.000 XXXXX
   81.000    94.500 XXXXX
   81.000    96.000 XXXXX
   81.000    97.500 XXXXX
   81.000    99.000 6.7627
   81.000   100.500 7.4097
   81.000   102.000 7.9307
...
```

Missing values are printed with XXXXX

Questions ?

Practicals

- Work on ecs in your $SCRATCH

```
cd $SCRATCH
```

- Make a copy of the practicals directory in your $SCRATCH

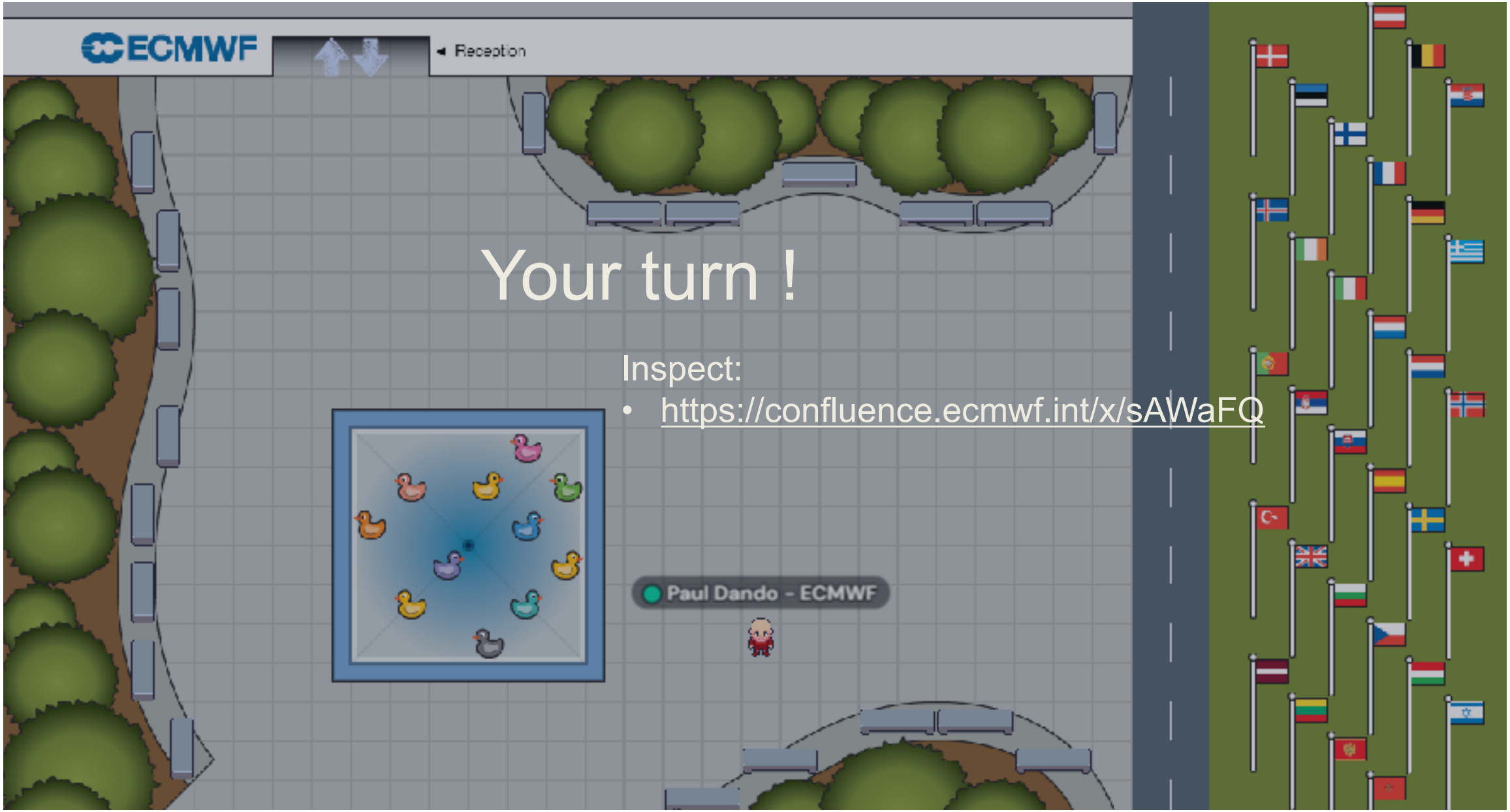
```
tar -xvf /home/trx/grib_practicals.tar
```

- This will create a directory in your $SCRATCH containing the GRIB data files for all today's practicals
- There are sub-directories for each practical:

```
ls $SCRATCH/grib_practicals
inspect modify python
```

- Remember to load the ecmwf-toolbox !

```
module load ecmwf-toolbox
```


ECMWF
Reception
Your turn !
Inspect:
• https://confluence.ecmwf.int/x/sAWaFQ
Paul Dando - ECMWF

grib_copy – copy contents of GRIB files

- Use grib_copy to copy selected contents of GRIB files optionally printing some key values
- Without options grib_copy prints no key information
- Options exist to specify the set of keys to print
  - Use verbose option (`-v`) to print keys
- Output can be ordered
  - E.g. order by ascending or descending step
- Key values can be used to specify the output file names
- grib_copy fails if a key is not found
  - Use the `-f` option to force grib_copy not to fail on error

grib_copy – examples

- To copy only fields at 100 hPa from a file

```
$ grib_copy -w level=100 in.grib1 out.grib1
```

- To copy only those fields that are not at 100 hPa

```
$ grib_copy -w level!=100 in.grib1 out.grib1
```

- Information can be output using the –v and –p options

```
$ grib_copy -v -p shortName in.grib1 out.grib1
in.grib1
shortName
t
1 of 1 grib messages in in.grib1
1 of 1 total grib messages in 1 files
```

grib_copy – using key values in output file

- Key values can be used to specify the output file name

```
$ grib_copy in.grib "out_[shortName].grib"

$ ls out_*

out_2t.grib  out_msl.grib ...
```

Use quotes to protect the [ ]s

This provides a convenient way to filter GRIB messages into separate files

grib_set – set key / value pairs

- Use grib_set to
  - Set key / value pairs in the input GRIB file
  - Make simple changes to key / value pairs in the input GRIB file
- By default all GRIB messages in input file are written to the output file

`-s key1=val1,key2=val2,…`	List of key / values to set
`-p key1,key2,…`	Keys to print (only with **`-v`**)
`-w key1=val1,key2!=val2…`	Where option
`-d value`	Set all data values to **`value`**
`-f`	Do *not* fail on error
`-v`	Verbose
`-S`	Strict – copy only messages matching all constraints
`-r`	Repack data when changing packing algorithm

`...`

grib_set – examples

- To set the parameter value of a field to 10m wind speed (10si)

```
$ grib_set -s shortName=10si in.grib1 out.grib1
```

- This changes e.g.
  - shortName to 10si
  - paramId to 207
  - name / parameterName to ‘10 metre wind speed’
  - units / parameterUnits to ‘m s ** -1’
  - indicatorOfParameter to 207
  - marsParam to 207.128

grib_set – examples

- Some keys are read-only and cannot be changed directly

```
$ grib_set -s name="10 metre wind speed" in.grib1 out.grib1

ECCODES ERROR   :  grib_set_values[0] name (3) failed: Value is read only
```

- The read-only keys can only be set by setting one of the other keys, e.g.
  - shortName=10si
  - paramId=207
  - indicatorOfParameter=207

grib_set – modify data values

- An offset can be added to all data values in a GRIB message by setting the key offsetValuesBy

```
$ grib_get -F "%.5f" -p max,min,average TK.grib
315.44727 216.96680 286.34257

$ grib_set -s offsetValuesBy=-273.15 TK.grib TC.grib

$ grib_get -F "%.5f" -p max,min,average TC.grib
42.29726 -56.18321 13.19257
```

grib_set – modify data values

- The data values in a GRIB message can be multiplied by a factor by setting the key scaleValuesBy

```
$ grib_get -F "%.2f" -p max,min,average Z.grib
65035.92 -3626.08 2286.30

$ grib_set -s scaleValuesBy=0.102 Z.grib1 orog.grib1

$ grib_get -F "%.2f" -p max,min,average orog.grib1
6633.64 -369.86 233.20
```

grib_set – using key values in output file

- Key values can be used to specify the output file

```
$ grib_set -s time=0000 in.grib "out_[shortName].grib"


$ ls out_*
out_2t.grib  out_msl.grib ...
```

Remember: use quotes to protect the []s !

What cannot be done with grib_set

- grib_set cannot be used for making transformations to the data representation
  - It cannot be used to transform data from spectral to grid-point representation (and vice-versa)
- grib_set cannot be used transform data from one grid representation to another
  - It cannot be used to transform data from regular or reduced Gaussian grids to regular latitude-longitude grids
- grib_set cannot be used to select sub-areas of data
  - It will change the value of, e.g. latitudeOfFirstGridPointInDegrees etc, but the data will still be defined on the original grid

✗ *GRIB tools cannot be used to interpolate the data*

grib_to_netcdf – convert GRIB to netCDF

- Input GRIB fields must be on a regular grid
  - typeOfGrid=regular_ll or regular_gg

-o output_file	Output netCDF file
-R YYYYMMDD	Use **YYYYMMDD** as reference date (default: 19000101)
-D NC_DATATYPE	NetCDF data type: NC_BYTE, NC_SHORT (default), NC_INT, NC_FLOAT or NC_DOUBLE
-k kind	Kind of file to be created: 1 → netCDF classic file format 2 → netCDF 64 bit classic file format (Default) 3 → netCDF-4 file format 4 → netCDF-4 classic model file format
-T	Do not use time of validity.
-u dimension	Set **dimension** to be an unlimited dimension
...	

Used by the MARS WebAPI to provide data in netCDF

grib_to_netcdf – examples

- To convert the fields in file.grib1 to NetCDF

```
$ grib_to_netcdf -o out.nc file.grib1
grib_to_netcdf: Version 2.2.0
grib_to_netcdf: Processing input file 'file1.grib1'.
grib_to_netcdf: Found 1 GRIB fields in 1 file.
grib_to_netcdf: Ignoring key(s): method, type, stream, refdate, hdate
grib_to_netcdf: Creating netCDF file 'out1.nc'
grib_to_netcdf: NetCDF library version: 4.3.2 of May 10 2016 11:12:41 $
grib_to_netcdf: Creating large (64 bit) file format.
grib_to_netcdf: Defining variable 't2m'.
grib_to_netcdf: Done.

> ls -s out.nc
160 out.nc
```

grib_to_netcdf – examples

- To convert the fields in file.grib1 to NetCDF with data type set to NC_FLOAT

```
$ grib_to_netcdf -D NC_FLOAT -o out.nc file.grib1
grib_to_netcdf: Version 2.2.0
grib_to_netcdf: Processing input file 'file1.grib1'.
grib_to_netcdf: Found 1 GRIB fields in 1 file.
grib_to_netcdf: Ignoring key(s): method, type, stream, refdate, hdate
grib_to_netcdf: Creating netCDF file 'out1.nc'
grib_to_netcdf: NetCDF library version: 4.3.2 of May 10 2016 11:12:41 $
grib_to_netcdf: Creating large (64 bit) file format.
grib_to_netcdf: Defining variable 't2m'.
grib_to_netcdf: Done.

> ls -s out.nc
316 out.nc
```

Output NetCDF file is about twice the size

ecCodes user interfaces

- For some processing it is more convenient – or even necessary – to write a program
- The ecCodes library supports three user interfaces:
  - C: `#include <eccodes.h>`
  - Fortran 90 interface: `use eccodes`
  - Python interface: `import eccodes`
- At ECMWF two environment variables ECCODES_INCLUDE and ECCODES_LIB are defined to aid compilation and linking of Fortran 90 and C programs
- On Atos:

```
module load ecmwf-toolbox

gcc  myprog.c $ECCODES_INCLUDE $ECCODES_LIB -lm

gfortran myprog.f90 $ECCODES_INCLUDE $ECCODES_LIB
```

General framework for decoding

- Open one or more GRIB files (for read or write)
  - Standard Fortran calls cannot be used to open a GRIB file – you must use codes_open_file
- Calls to load one or more GRIB messages into memory
  - Two main subroutines: codes_grib_new_from_file / codes_new_from_index
  - These return a unique identifier used to manipulate the loaded GRIB messages
- Calls to decode the loaded GRIB messages – only loaded GRIB messages can be decoded
  - codes_get
  - Decode only what you need (not the full message !)
- Release the loaded GRIB messages:
  - codes_release
- Close the opened GRIB files
  - Standard Fortran calls cannot be used to close a GRIB file – you must use codes_close_file

ecCodes – Python API decoding example

```
import sys
from eccodes import *

# Load all the GRIB messages contained in file.grib1
ifile = open('file.grib1‘,’rb’)
while 1:
    igrib = codes_grib_new_from_file(ifile)
    if igrib is None: break

    # Decode data from the loaded message
    date = codes_get( igrib , “dataDate”)
    levtype = codes_get(igrib, “typeOfLevel”)
    level = codes_get(igrib, “level”)
    values = codes_get_array(igrib, “values”)
    print (“%s %s %d %.5f %.5f” % (date, levtype, level, values[0], values[-1]))

    # Release
    codes_release(igrib)
ifile.close()
```

Decode as little as possible !
You will never decode all the loaded GRIB message

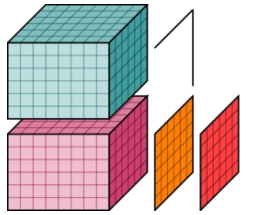
Loop on all the messages in a file. A new grib message is loaded from file. igrib is the grib id to be used in subsequent calls

Values returned as an array

Release the memory !

ecCodes and cfgrib

- cfgrib provides a Python interface to map GRIB files to the netCDF Common Data Model following the CF Convention using ecCodes.
- The high level enables the engine='cfgrib' option to read GRIB files with xarray
- Inspired by netCDF4-python and h5netcdf
- ecCodes used for low-level decoding



xarray

- Install from conda

```
$ conda install -c conda-forge cfgrib
```

- Or PyPI

```
$ pip install cfgrib
```

```
>>> import xarray as xr
>>> ds = xr.open_dataset('era5-levels-members.grib',
engine='cfgrib')
>>> ds
<xarray.Dataset>
Dimensions:         (isobaricInhPa: 2, latitude: 61,
longitude: 120, number: 10, time: 4)
Coordinates:
  * number          (number) int64 0 1 2 3 4 5 6 7 8 9
  * time            (time) datetime64[ns] 2017-01-01
... 2017-01-02T12:00:00
    step            timedelta64[ns] ...
  * isobaricInhPa   (isobaricInhPa) float64 850.0 500.0
  * latitude        (latitude) float64 90.0 87.0 84.0
81.0 ... -84.0 -87.0 -90.0
  * longitude       (longitude) float64 0.0 3.0 6.0 9.0
... 351.0 354.0 357.0
    valid_time      (time) datetime64[ns] ...
```

https://github.com/ecmwf/cfgrib

ecCodes can do more…

- The idea is to provide a set of high-level keys or subroutines to derive / compute extra information from a loaded GRIB message
- For example:
  - keys (READ-ONLY) to return average, min, max of values, distinct latitudes or longitudes, etc …
  - Routines to compute the latitude, longitude and values
    - codes_grib_get_data
  - Routines to extract values
    - codes_grib_find_nearest: extract values closest to given geographical points
    - codes_get_element: extract values from a list of indexes
  - Routines for indexed access
    - Usually much faster than sequential access for “random” access

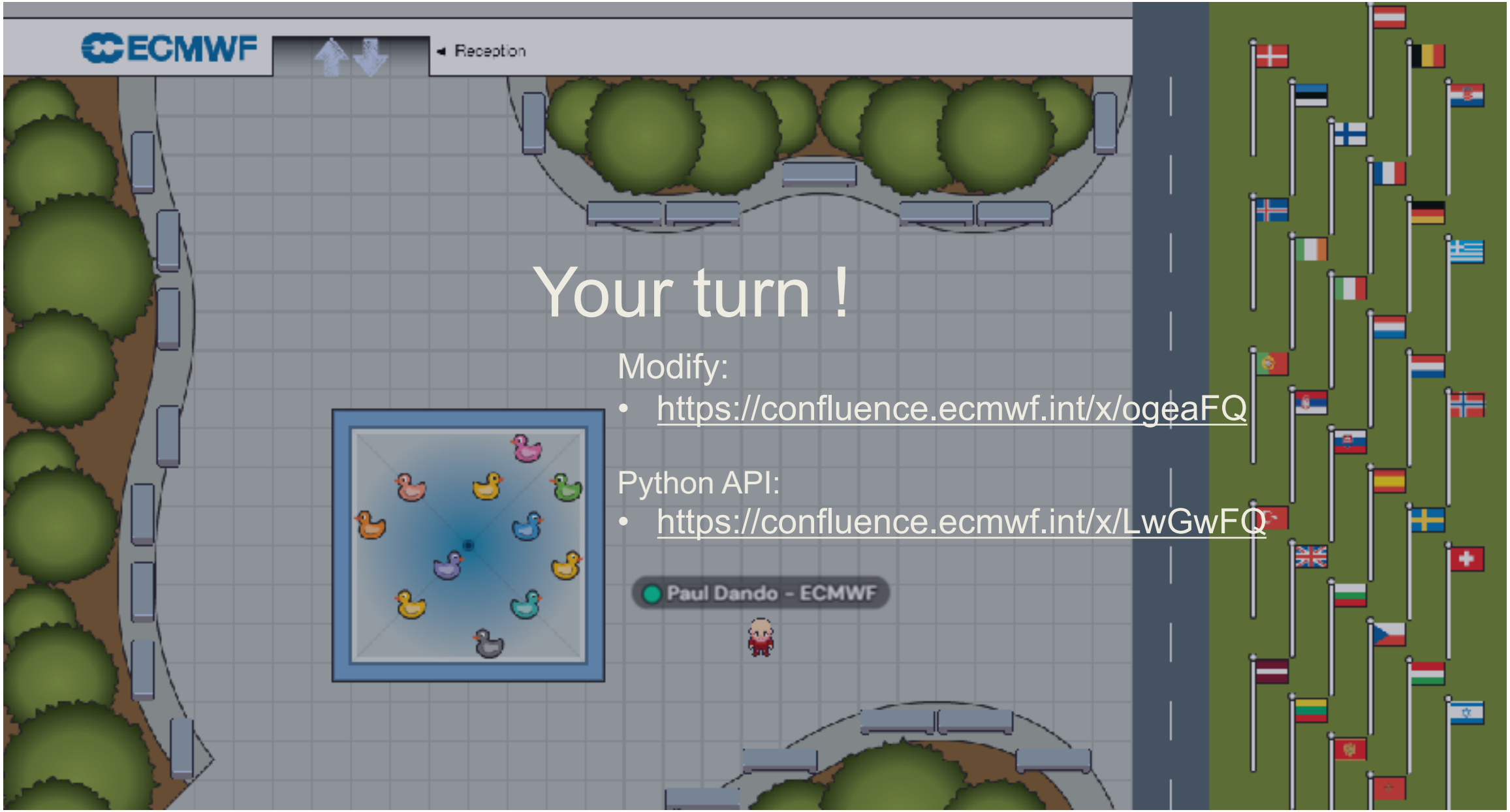
For lat/lon, Gaussian, reduced Gaussian grids. It is similar to the grib_get_data GRIB tool

Similar to "grib_ls -l "or "grib_get -l"

GRIB decoding – summary

Use GRIB Tools where possible	• It is not always necessary to write a program !
Use edition-independent keys	• Provides transparent access to GRIB 1 and GRIB 2 messages
If you do need to write a program think carefully about how the fields are accessed	• Indexed access can be much faster than sequential access

Questions ?


ECMWF
Reception
Your turn !
Modify:
• https://confluence.ecmwf.int/x/ogeaFQ
Python API:
• https://confluence.ecmwf.int/x/LwGwFQ
Paul Dando - ECMWF