

# ECMWF and the Copernicus Climate Change Service: netCDF



Climate Change

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(With thanks to colleagues at ECMWF and Copernicus)





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# ECMWF Background

## European Centre for Medium-Range Weather Forecasts

An independent, intergovernmental organisation supported by many European nations, based at Reading UK.

### **Mission:**

- Produce numerical weather forecasts ;
- Scientific/technical research to improve forecast skill ;
- Maintain an archive of meteorological data .

ECMWF provides a range of products and services ***including:***  
Global numerical weather forecasts, Air quality analysis, Atmospheric composition monitoring, Climate monitoring, Ocean circulation analysis, Hydrological prediction...*and many more*

<https://www.ecmwf.int>



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## Requirements for storing netCDF in MARS

- The main repository of meteorological data at ECMWF is **MARS** (the **Meteorological Archival and Retrieval System**) ;
- It contains **>180 petabytes** of operational and research data, mainly in **GRIB** (1 & 2) and **BUFR**;
- netCDF is becoming **increasingly** used for storing data at ECMWF (e.g NEMO ocean data from CERA-20C)
- We would like to be able to archive these netCDF data in MARS **directly** ;
- ECMWF want to **make CF-netCDF a standards based “first class citizen”** by promoting its use and increasing the ability of our tools to support it.



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## Requirements for storing netCDF in MARS

- Files must be **compatible** with existing MARS infrastructure and systems;
- Needed to provide **guidance** on how CF-netCDF files should be formed for use at ECMWF;
- Issues addressed include **structure of the files, standard names, use of multiple time coordinates, cell methods, etc...**;
- A “**Recommendations**” document has been produced to summarise this work:  
<https://software.ecmwf.int/wiki/display/DGOV/Metadata+recommendations+for+encoding+NetCDF+products+based+on+CF+convention>  
(ECMWF web login required & may need to request access)



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# ECMWF Metadata Recommendations

The screenshot shows a web browser window with the URL <https://software.ecmwf.int/wiki/display/ECMWF/Metadata+recommendations+for+encoding+NetCDF+products+based+on+CF+convention>. The page title is "Metadata recommendations for encoding NetCDF products based on CF convention". The content is a hierarchical list of recommendations:

- Authors
- Status
- Abstract
- Revision history
- 1 Introduction
  - 1.1 Data models, standards and conventions
- 2 Data Fields
- 3 Coordinate systems
  - 3.1 Horizontal coordinate systems
    - 3.1.1 Regular longitude and latitude
    - 3.1.2 Regular projection grids
    - 3.1.3 Regular non-projection grids: NEMO/ORCA case
  - 3.2 Vertical coordinate systems
    - 3.2.1 Near-surface fields
    - 3.2.2 Isobaric levels
    - 3.2.3 Depth levels
  - 3.3 Time coordinate systems
    - 3.3.1 Analysis time: the forecast reference time
    - 3.3.2 Forecast: the forecast period
    - 3.3.3 Valid time
  - 3.4 Realization discrete coordinates
- 4 Missing and valid data
- 5 Aggregations
  - 5.1 Daily maximum near-surface temperature
  - 5.2 Monthly mean of daily maximum near-surface temperature
- 6 Properties for data discovery
- 7 Examples
  - 7.1 UERRA project dataset
    - Sea surface temperature
    - Minimum temperature at 2 metres since previous post-processing
    - Geopotential at isobaric levels
  - 7.2 C3S Seasonal dataset
  - 7.3 NEMO dataset from CERA-20C

Discusses:

- Standard names
- Spatial Coordinates
- Multiple time coordinates
- Realization
- Cell methods
- Aggregations
- Attributes
- Metadata

V1.0 Released July 2017

netCDF data in MARS ~ end 2017



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## Copernicus Services Background

- Copernicus is the **EU's earth observation programme**, and is directed by EU and ESA <http://www.copernicus.eu/> ;
- It has **3 components**: i) Space component ii) In-situ measurements iii) Services to users;
- There are **6 services** to users (each addressing a thematic area) which have been funded by the EU;
- ECMWF is the **entrusted entity** to run the **Copernicus Climate Change Service (C3S)** and the **Copernicus Atmospheric Monitoring Service (CAMS)**;
- The **Climate Data Store** will be at the heart of the C3S infrastructure and will provide information about **past, present and future** climate in terms of **Essential Climate Variables** and **derived climate indicators, and many more...**

<https://climate.copernicus.eu/climate-data-store>

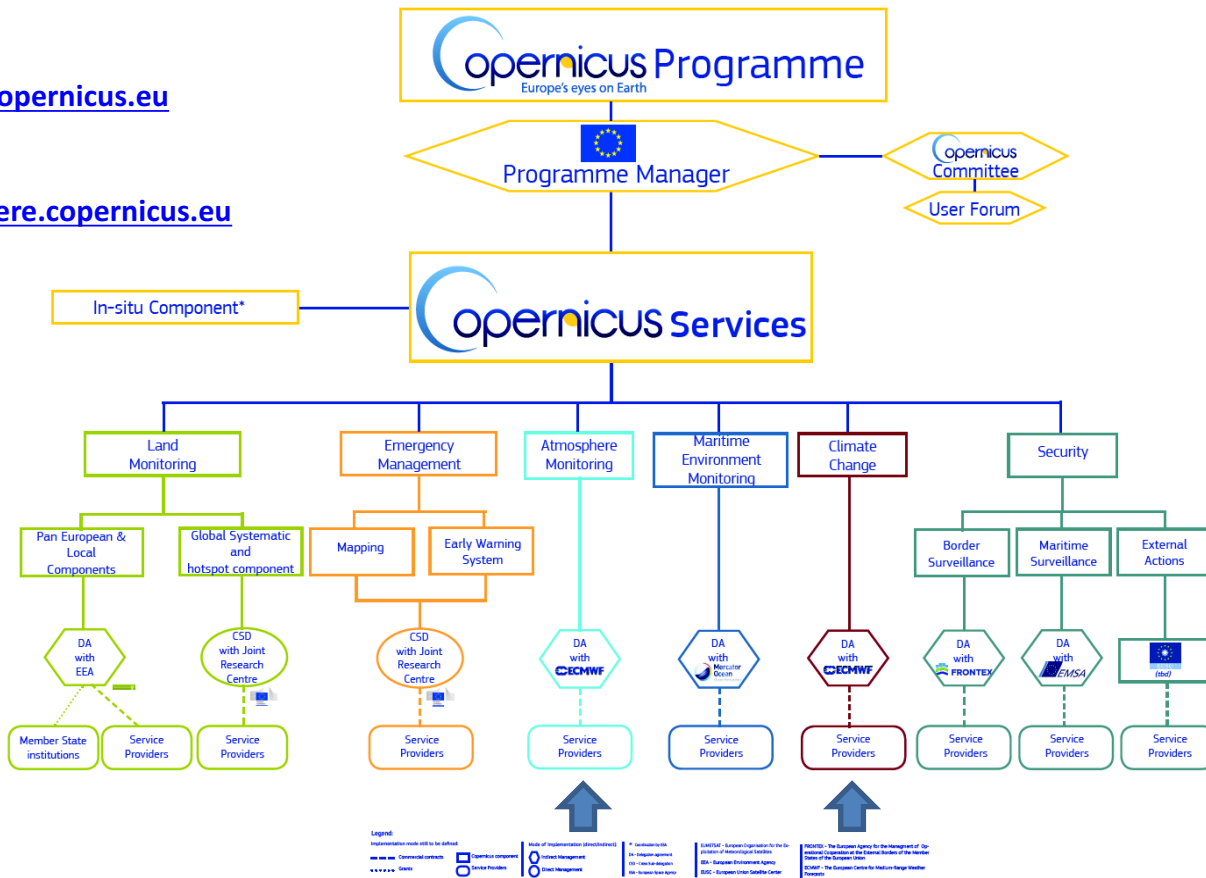


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# Copernicus Structure

**C3S:**  
<https://climate.copernicus.eu>

**CAMS:**  
<https://atmosphere.copernicus.eu>



<http://www.copernicus.eu/main/copernicus-brief>



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## C3S Seasonal Forecast Data

- Seasonal Forecast data is a **major dataset and service** for C3S/CDS
- **5 institutions** (ECMWF, Met Office, MF, DWD, CMCC) will provide Seasonal Forecast data to C3S, which will be used to produce products
- Need to build a **consistent** archive for users, and **operationally** produce multi-system products

We have therefore developed :

- A **netCDF standard** for C3S Seasonal Forecast data providers
  - Uses netCDF4 “classic” format
  - based on CF-1.6, SPECS, CMIP...

<https://software.ecmwf.int/wiki/display/C3SS/Guide+to+NetCDF+encoding+for+C3S+providers>

*(ECMWF web login required and may need to request access)*





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# C3S netCDF standard for Seasonal Data

The screenshot shows a web browser window with the following content:

- Browser address bar: `https://software.ecmwf.int/wiki/display/C3S/Guide+to+NetCDF+encoding+for+C3S+providers#`
- Page title: **Guide to NetCDF encoding for C3S providers**
- Created by Eduardo Penabad, last modified by Kevin Marsh on Aug 03, 2017
- WARNING**: Some modifications have been made in this page since the meeting at C3S General Assembly at Toulouse. Please check here
- Introduction**: During these first stages of the proof-of-concept phase of C3S seasonal forecast activity, we have been working to define a standard for the data provision in netCDF. This standard is described below. The proposal is constrained by the CF convention, and we also tried not to diverge from specifications coming from other well established communities: SPECS and CMIP5/6. Additionally ACDD has been also taken into account when defining the data discovery related metadata. Hence, the following links are valuable sources of information that have informed the definition of this proposal:
  - [CF convention](#)
  - [CF convention standard names tables](#)
  - [SPECS file content and format, data structure and metadata](#)
  - [CMIP5 list of variables](#)
  - [CMIP6 Data Request: MIP variables search](#)
  - [ACDD convention](#)
- Examples**: Some example files have been created following the guidelines contained in this document.

Defines:

- Exact structure of files
- Standard names
- Spatial Coordinates
- Multiple time coordinates
- Realization
- Cell methods
- Attributes
- Metadata

**V0.1 Released June 2017**

Expect **operational** netCDF data in this form by September 2017



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# C3S Seasonal Forecast Data

For the Seasonal Forecast data we have **also** developed:

## A **filename/directory** name convention

- Based on CMIP approach.

<https://software.ecmwf.int/wiki/display/C3SS/NetCDF+Dataset+Design+Overview>

*(ECMWF web login required and may need to request access)*

## A **netCDF file checker**

- Checks conformance to CF-1.6 and C3S-0.1 ;
- Command line tool;
- Python code, highly configurable using JSON config files for metadata and data constraints.

<https://software.ecmwf.int/stash/projects/CDS/repos/checker/browse>



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# netCDF Checker

The screenshot shows a web browser window displaying the Bitbucket repository for the 'netCDF checker' project. The page title is 'Copernicus Climate Data Store / checker'. The 'Source' section lists various files and folders, including 'bin', 'C3Checker', 'tests', '.gitignore', 'CHANGELOG.rst', 'CONTRIBUTING.rst', 'install-shell-module', 'LICENSE', 'MANIFEST.in', 'README.rst', 'requirements-tests.txt', 'requirements.txt', 'setup.cfg', 'setup.py', and 'test.py'. The 'bin' directory is currently selected. At the bottom of the page, there is a footer for Atlassian Bitbucket v4.14.1, with links for Documentation, Contact Support, Request a feature, About, and Contact Atlassian.

```
220817: bash: Konsole
File Edit View Bookmarks Settings Help
14:14:56 INFO - [references] : [The new CMCC Seasonal Prediction System, CMCC ...]
14:14:56 INFO - [institute_id] : [cmcc]
14:14:56 INFO - [modeling_realm] : [soil]
14:14:56 INFO - [keywords] : [Seasonal Forecasts, C3S, ECMWF, Copernicus, Cl ...]
14:14:56 INFO - [summary] : [Seasonal Forecast data produced by CMCC as 11s ...]
14:14:56 INFO - [institution] : [CMCC, Centro Euro-Mediterraneo sul Cambiament1 ...]
14:14:56 INFO - [_NCProperties] : [version=1|netcdf|lversion=4.4.1|hdFSL|lbersto ...]
14:14:56 INFO - [title] : [CMCC seasonal forecast model output prepared f ...]
14:14:56 INFO - [forecast_type] : [InIrcast]
14:14:56 INFO - [conventions] : [CF-1.6 C3S-0.1]
14:14:56 INFO - [project] : [C3S Seasonal Forecast]
14:14:56 INFO - [source] : [CMCC-CM2-v20160423: atmos: CAM5 (ne30np4 spect ...]
14:14:56 INFO - [contact] : [http://copernicus-support.ecmwf.int]
14:14:56 INFO - [commit] : [2017-04-01T11:48:25Z https://software.ecmwf.in ...]
14:14:56 INFO - [level_type] : [surface]
14:14:56 INFO - [history] : []

CF CHECKINGS:
14:14:56 WARNING - [CFREF-ch4]- Axis E is not part of CF 1.6 but may be allowed in CF 1.7 - for variable [realization]
14:14:56 WARNING - [CFREF-ch3.4]- Calendar is recommended for the time coordinate variable [leadtime]
14:14:56 WARNING - [CFREF-ch3.4]- Month_length attribute is recommended when the calendar is not declared for the time coordinate variable [leadtime]
14:14:56 WARNING - [CFREF-ch3.2/3.4]- Standard_name attribute [moisture_content_of_soil_water] not CF compliant for variable [mr1sl]
14:14:56 WARNING - [CFREF-ch3.1]- Units cannot be compared with standard name canonical unit - Std name does not exist or canonical unit invalid [u'mo
isture_content_of_soil_water']
14:14:56 ERROR - [CFREF-ch3.1]- Units [hours since YYYY-MM-DDThh:mm:ss+TZhh:Tzmm] is not recognized by UDUNITS2 library for variable [reftime]
14:14:56 ERROR - [CFREF-ch3.1]- Units [hours since YYYY-MM-DD hh:mm:ss TZhh:Tzmm] is not recognized by UDUNITS2 library for variable [ttime]

C3S CHECKINGS:
14:14:56 ERROR - [C3S-MetadataCheck-Mandatory_netcdf_format]-File Format [NETCDF4_CLASSIC] is mandatory - currently [NETCDF3_CLASSIC]
14:14:56 ERROR - [C3S-MetadataCheck-Mandatory_global_attributes_content_date]-Global Attribute [creation_date] value is not allowed - Incorrect data
format [2017-08-01T13:02:58] - It should be [%Y-%m-%dT%H:%M:%SZ]
14:14:56 ERROR - [C3S-MetadataCheck-Mandatory_global_attributes_content_date]-Global Attribute [forecast_reference_time] value is not allowed - Inco
rrect data format [2013-08-01T00:00+00:00] - It should be [%Y-%m-%dT%H:%M:%SZ]
14:14:56 ERROR - [C3S-MetadataCheck-Mandatory_dimensions_per_variablename]-NetCDF Dimensions must contain depth used for variable mr1sl - currently
```

## Provides:

- File summary
  - Results of CF-1.6 checks
  - Results of User/project defined checks
- ## Checker released July 2017



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## The CDS Toolbox

- The toolbox will make use of **all** the datasets available in the CDS ;
- The **wide variety** of volumes, data types, formats and structures makes their combined use highly challenging ;
- Will allow the users to develop web based processing (**applications**) ;
- Available operations inc. differences, regridding, statistical computations (**tools**) ;
- Combine tools and present results to users (**workflows**) ;

To achieve this a **Common Data Model** is also being developed:

- Built on netCDF recommendations document we have produced (referred to earlier)



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# Toolbox CDM

The screenshot shows a web browser window displaying the ECMWF website. The page title is "CDM: Common data model -specification". The breadcrumb trail is "Pages / C3S Toolbox / Project documents". The page content is a table of contents for the specification document, listing sections 1 through 7 with their respective sub-sections.

- document identification
- 1. Background
  - 1.1 Expected evolution of the Climate Data Store
  - 1.2 Pre-existing data formats and data models
- 2. Data Format
- 3. Data Structure
  - 3.1 Data Fields
  - 3.2 Data categories
- 4. Axis and Coordinates
  - 4.1 Horizontal coordinates
  - 4.2 Vertical coordinates
  - 4.3 Time Coordinates
  - 4.4 Realization
  - 4.5 Additional axis
  - 4.6 Bound coordinates
    - 4.6.1 Time Bounds
    - 4.6.2 Spatial coordinates bounds
- 5. Naming Conventions
  - 5.1 Standard names
  - 5.2 Long names
  - 5.3 Short names
  - 5.4 File naming
- 6. Units
- 7. Track operations on data
  - 7.1 Use of cell\_methods attribute
    - 7.1.1 Subsequent operations
    - 7.1.2 Operations leading to reduction of dimensionality
    - 7.1.3 Time mean, maximum and minimum
    - 7.1.4 Climatological Statistics
  - 7.2 Operations not included in methods

- Based on the ECMWF “Recommendations” document
- Basis for Toolbox data handling

**Expected Release ~ end of 2017**



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# We welcome any feedback you have...

# Thank you

The screenshot shows the Copernicus Climate Change Service homepage. At the top, there are logos for Copernicus and Climate Change Service, along with social media icons and a 'Contact us' button. A navigation bar includes links for Home, About C3S, NEWS & MEDIA, EVENTS, TENDERS, PRODUCTS, SERVICES, and HELP & SUPPORT. The main banner features a collage of images (sunset, city, port) with the text 'CLIMATE INFORMATION FOR YOUR PLANNING'. Below the banner are three sections: 'IN FOCUS' with a link to 'C3S\_330 Operational Production of Seasonal Forecasts', 'MONTHLY MAPS & CHARTS' with a link to 'Monthly maps and charts of essential climate variables', and 'NEWS' with a link to 'C3S releases powerful new climate change "encyclopaedia" for public use'.

The screenshot shows the Copernicus Climate Data Store (CDS) homepage. It features the Copernicus and Climate Change Service logos, a search bar, and a 'Login/register' button. The main heading is 'Climate Data Store (CDS)'. Below this, there is a paragraph explaining the store's purpose: 'The Copernicus Climate Data Store supports scientists, policy makers and businesses by providing authoritative, quality-assured information about the past, current and future states of the climate in Europe and worldwide.' A search bar is provided with the text 'Discover data and resources in our catalogue'. Below the search bar are three featured data products: 'Access Greenhouse Gases data products (CO<sub>2</sub> and CH<sub>4</sub>)', 'Access Land Cryosphere data products (Sea Ice, Glaciers)', and 'Access the C3S Climate Reanalysis (ERAS)'. The footer includes navigation links for About C3S, Contact us, Disclaimer / Privacy, and Cookies, along with logos for Copernicus and ECMWF.

<https://climate.copernicus.eu>

<https://www.ecmwf.int>

