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A brief introduction to the netCDF format and THREDDS data server Arild Burud - IT - MET Norway WeADL 2021 Workshop

The workshop is organized under the umbrella of WeaMyL, project funded by the EEA and Norway Grants under the RO-NO-2019-0133. Contract: No 26/2020

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Topics: NetCDF - THREDDS - OPeNDAP

Acronyms - once you know them they become friends...

NetCDF: "Network Common Data Form"

TDS: "THREDDS Data Server"

THREDDS: "Thematic Real-time Environmental Distributed Data Services"

OPeNDAP: "Open-source Project for a Network Data Access Protocol" CF Conventions: "NetCDF Climate and Forecast Metadata Conventions" ACDD: "Attribute Convention for Dataset Discovery" COARDS: "Cooperative Ocean/Atmosphere Research Data Service" FIMEX: "File Interpolation, Manipulation and EXtraction library for gridded geospatial data"





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thredds.met.no

https://thredds.met.no is using the TDS software from Unidata/UCAR.

- We use it to publish data in NetCDF format
- Typically gridded data or timeseries



Monthly averaged Sea Ice Extent from Arctic Monthly Mean Sea Ice Extent (km'†)

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https://en.wikipedia.org/wiki/NetCDF

NetCDF (Network Common Data Form) is a set of software libraries and self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data. ... The format is an open standard. NetCDF Classic and 64-bit Offset Format are an international standard of the Open Geospatial Consortium. The project started in 1988 and is still actively supported by UCAR. The original netCDF binary format (released in 1990, now known as "netCDF classic format") is still widely used across the world and continues to be fully supported in all netCDF releases. Version 4.0 (released in 2008) allowed the use of the HDF5 data file format. ... Version 4.7.0 (2019) added support for reading Amazon S3 objects. Version 4.8.0 (2021) with Zarr support.

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Basic components of a NetCDF file



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Self-describing format





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netCDF Conventions

Format conventions ensure cross-compatibility and makes it easier to understand/extract information. MET recommends CF Convention, ACDD, COARDS, etc... See https://www.unidata.ucar.edu/software/netcdf/conventions.html Conventions regulate the use of attributes and naming schemes.

```
short temperature(time, depth, Y, X) ;
    temperature:units = "Celsius" ;
    temperature:standard_name =
"sea_water_potential_temperature";
```



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Data Sources

NetCDF-files come from our own production chains and from (inter)national partners, at MET Norway we store these on our lustre storage system. The files can be presented on thredds.met.no as individual files, ncml-files or as aggregated datasets. Example:

\$ ls -l barents_opera/zdepths/
total 22893812

-rw-r--1 xxx yyy 3471331596 Jun 12 11:43 Barents-2.5km ZDEPTHS his.an.2020061100.nc -rw-rw-r-- 1 xxx yyy 3271502854 Jun 15 07:50 Barents-2.5km ZDEPTHS his.an.2020061200.nc -rw-rw-r-- 1 xxx yyy 3274018343 Jun 15 07:53 Barents-2.5km ZDEPTHS his.an.2020061300.nc -rw-rw-r-- 1 xxx yyy 3475706944 Jun 15 21:21 Barents-2.5km ZDEPTHS his.an.2020061400.nc -rw-rw-r-- 1 xxx yyy 9950665619 Jun 15 21:21 Barents-2.5km ZDEPTHS his.an.2020061400.nc

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Looking at thredds.met.no

← → C

thredds.met.no/thredds/fou-hi/fou-hi.html

☆ =J 🚱 :

Norwegian Meteorologica Catalog https://thredds.met.no/thredds/fou-hi/fou-hi.html

Terms of service

This is a shared public service which may experience overload in traffic from time to time. If you require priority access for your own operational service please contact us at servicedesk@met.no

MET Norway's Privacy Policy

Get messages about planned maintenance and incidents from our status page.

NOTE: Big change in MEPS on February 4th 2020, affecting file path, contents, and timeliness.

• All consumers of our MEPS weather forecasts will be affected. Please see https://thredds.met.no/thredds/metno.html for complete announcement in Norwegian. If you need a translation get in touch with us on servicedesk@met.no.

NOTE: Access through http to this service is deprecated

. From Tuesday 11th of February 2020 10 UTC we permanently reply with http error code 410 on plain http (scripts must initiate directly on https)

Ocean and sea ice forecasts

Example scripts to process data Thredds introduction and MATLAB documentation

Dataset	Size	Last Modified
Ceean and Sea Ice		
a met.no ROMS NorKyst8800m coastal ocean forecasting system (2019_)/		
a met.no OLD ROMS NorKyst800m coastal ocean forecasting system (2012-2019)/		
met.no ROMS Norshelf 2.4km regional ocean forecasting system/		
met.no ROMS Nordic4km regional ocean and sea ice forecasting system/		
a met.no ROMS Arctic20km ocean and sea ice forecasting system (Production ends May 2, 20171)/		
a met.no Topaz4 Arctic Physical ocean and sea ice forecasting system (unmasked)/		
🖨 met.no Barents-2.5km regional ocean and sea ice forecasting system/		
a Waves		
😑 met.no MyWaveWAM8km Nordic Seas wave forecasting system (best estimate) (deprecated after Feb 11, 2020)/		
a met.no MyWaveWAM4km Nordic Seas wave forecasting system (archive and best estimate)/		
met.no MyWaveWAM800m Norwegian Coastal wave forecasting system/		
in met.no MyWayeWAMBkm Nordic Seas wave forecasting system (archive and a deprecated best estimate that covers 2016 June-December)/		
Cooperative operations		
CMEMS (formerly MyOcean)/		
DSI SAF/		

MET Norway Thredds Service at Norwegian Meteorological Institute see in THREDDS Data Server IVersion 4.6.14-metno1 - 2019-07-24T08:01:30+0000

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Many datasets can be accessed as either individual files or an aggregation of all files along the time axis. Imagine stitching together 24 hour spans and presenting it as a complete file (although not downloadable as a file) that cover years of results.

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Web view - individual files

Dataset		
Dataset		
🔲 Barents-2.5km regi	onal ocean and sea ice foreca	sting system
met.no Barents-2	.5km Files/	
met.no Barents-2.5km	n Hourly Aggregated	
ataset	Size	Last Modified
met.no Barents-2.5km Files	Size	Last Modified
ataset met.no Barents-2.5km Files Barents-2.5km ZDEPTHS his.fc.nc	Size 9.950 Gbytes	Last Modified
ataset imate: imate: imate: imate: Barents-2.5km_ZDEPTHS_his.fc.nc Barents-2.5km_ZDEPTHS_his.an.2020061400.nc	Size 9.950 Gbytes 3.475 Gbytes	Last Modified
met.no Barents-2.5km Files Barents-2.5km_ZDEPTHS_his.fc.nc Barents-2.5km_ZDEPTHS_his.an.2020061400.nc Barents-2.5km_ZDEPTHS_his.an.2020061300.nc	Size 9.950 Gbytes 3.475 Gbytes 3.274 Gbytes	Last Modified 2020-06-15T21:21:36Z 2020-06-15T21:21:11Z 2020-06-15T07:53:40Z
ataset imate: imate: imate: <td< td=""><td>Size 9.950 Gbytes 3.475 Gbytes 3.274 Gbytes 3.271 Gbytes</td><td>Last Modified 2020-06-15T21:21:36Z 2020-06-15T21:21:11Z 2020-06-15T07:53:40Z 2020-06-15T07:50:07Z</td></td<>	Size 9.950 Gbytes 3.475 Gbytes 3.274 Gbytes 3.271 Gbytes	Last Modified 2020-06-15T21:21:36Z 2020-06-15T21:21:11Z 2020-06-15T07:53:40Z 2020-06-15T07:50:07Z

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Individual files



al MET Norway Thredds Service THREDDS Data Server

Catalog https://thredds.met.no/thredds/catalog/barents25km_files/catalog.html

Dataset: met.no Barents-2.5km Files/Barents-2.5km_ZDEPTHS_his.fc.nc

- Data size: 9.950 Gbytes
- ID: barents25km_files/Barents-2.5km_ZDEPTHS_his.fc.nc

Access:

- 1. OPENDAP: /thredds/dodsC/barents25km_files/Barents-2.5km_ZDEPTHS_his.fc.nc
- 2. HTTPServer: /thredds/fileServer/barents25km_files/Barents-2.5km_ZDEPTHS_his.fc.nc
- 3. WMS: /thredds/wms/barents25km_files/Barents-2.5km_ZDEPTHS_his.fc.nc
- 4. WCS: /thredds/wcs/barents25km_files/Barents-2.5km_ZDEPTHS_his.fc.nc

Dates:

• 2020-06-15T21:21:36Z (modified)

Viewers:

- Godiva2 (browser-based)
- NetCDF-Java ToolsUI (webstart)

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Visualizing through Godiva2

🗧 🔶 C 🔒 thredds.met.no/thredds/godiva2/godiva2.html?server=https://thredds.met.no/thredds/wms/barents25km files/Barents-2.5km ZDEPTHS his.fc.nc



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Web view - aggregation

Dataset

Barents-2.5km regional ocean and sea ice forecasting system

met.no Barents-2.5km Files/

met.no Barents-2.5km Hourly Aggregated

Norwegian Meteorological Institute MET Norway Thredds Service

Catalog https://thredds.met.no/thredds/fou-hi/barents25.html

Dataset: Barents-2.5km regional ocean and sea ice forecasting system/met.no Barents-2.5km Hourly Aggregated

Data type: GRID
ID: barents25km agg

Access:

1. OPENDAP: /thredds/dodsC/barents25km_agg 2. WMS: /thredds/wms/barents25km_agg 3. WCS: /thredds/wcs/barents25km_agg

Viewers:

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- Godiva2 (browser-based)
 NetCDF-Java ToolsUI (webstart)
- Integrated Data Viewer (IDV) (webstart)



OPeNDAP Dataset Access Form

Action.	Get ASCII Get Binary Show Help
Data URL:	https://thredds.met.no/thredds/dodsC/barents25km_agg
Global Attributes:	file: /home/havis/run/barents-2.5km/ocean_his_AN.nc Conventions: CF-1.4, SGRID-0.3 type: ROMS/TOMS history file title: Barents-2.5km - ROMS var info: /home/havis/sea/ROMS/metroms apps/barents-
Variables:	CS_ľ: Array of 64 bit Reals [s_rho = 041]
	<pre>long name: S-coordinate stretching curves at RHO-points valid min: -1.0 valid max: 0.0 field: Cs r, scalar ChunkSizes: 42</pre>
	CS_W: Array of 64 bit Reals [s_w = 042]
	long name: S-coordinate stretching curves at W-points valid_min: -1.0 valid_max: 0.0 field: Cs_w, scalar ChunkSizes: 43
	□ X: Array of 32 bit Reals [X = 0738] X:
	axis: X long name: x-coordinate in Cartesian system standard_name: projection_x_coordinate units: m chueiciana 700

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Find Jan Mayen seatemp at 25m

← → C 🔒 thredds.met.no/thredds/godiva2/godiva2.html?server=https://thredds.met.no/thredds/wms/barents25km_agg#



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Through OPeNDAP webpage ?

	coordinates: ULON ULAT time cell measures: area: uarea missIng value: 1.0E30
	ice_V: Grid time: Y: X:
	units: m/s long name: ice velocity (y) coordinates: ULON ULAT time cell measures: area: uarea missing value: 1.0E30
	Salinity: Grid
	time: depth: Y: X:
Needs index 0-N	grid: grid location: face field: salinity, scalar, series FillValue: 1.0E37 grid mapping: projection 1
	temperature: Grid
	<pre>time: depth: Y: X: units: Celsius grid: grid location: face field: temperature, scalar, series FillValue: 1.0E37 grid_mapping: projection 1 long_name: Sea water potential temperature standard_name: sea_water_potential_temperature time: time coordinates: lon lat time</pre>
5/28/2021	ChunkSizes: 1, 1, 949, 739

LIME: Array of 64 bit Reals [time = 0..162]

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Use fimex with natural coordinates

Jan Mayen is located near 70N, 8W

```
$ fimex
--input.file=https://thredds.met.no/thredds/dodsC/barents25km agg
--input.type=netcdf --output.type=nc4
--extract.selectVariables=temperature
--extract.reduceToBoundingBox.south 69.
--extract.reduceToBoundingBox.north 72.
--extract.reduceToBoundingBox.west -10.
--extract.reduceToBoundingBox.east -7.
--extract.reduceVerticalAxis.start=20.
--extract.reduceVerticalAxis.end=30.
--extract.reduceVerticalAxis.unit=m
--extract.reduceTime.start=2020-06-16T00:00:00
--extract.reduceTime.end=2020-06-16T23:00:00
--output.file=mysubset.nc4
                                              Notice: original 24 hour file was >3GB
$ ls -l mysubset.nc4
-rw-rw-r-- 1 myid group 900475 Jun 16 08:04 mysubset.nc4
```

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What does it look like?

```
$ ncdump -h mysubset.nc4
netcdf mvsubset {
dimensions:
        X = 80:
        Y = 142:
        depth = 1;
        time = 24:
variables:
        float X(X) :
                 X:axis = "X" ;
                 X:long name = "x-coordinate in Cartesian system";
                 X:standard name = "projection x coordinate" ;
                 X:units = "m" ;
        float Y(Y) :
                 Y:axis = "Y" ;
                 Y:long name = "v-coordinate in Cartesian system" ;
                 Y:standard name = "projection y coordinate" ;
                 Y:units = \overline{m};
        double depth(depth) ;
                 depth:units = "m" ;
                 depth:positive = "down" ;
                 depth:axis = "Z" ;
                 depth:standard name = "depth" ;
        int projection 1 ;
                 projection 1:grid mapping name =
"lambert conformal conic" ;
                 projection 1:proj4 = "+proj=lcc +lat 0=77.5 +lon 0=-25
+lat 1=77.5 +lat 2=77.5 +no defs +R=6.371e+06";
        double time(time) ;
                 time:long name = "time since initialization" ;
                 time:units = "seconds since 1970-01-01 00:00:00";
                 time:calendar = "gregorian";
                 time:field = "time, scalar, series";
                 time:axis = "T" ;
                 time:standard name = "time" ;
```

```
double lat(Y, X) ;
                lat:long name = "latitude of RHO-points" ;
                lat:units = "degree north" ;
                lat:standard name = "latitude" ;
                lat:grid mapping = "projection 1" ;
                lat:field = "lat, scalar";
        double lon(Y, X) ;
                lon:long name = "longitude of RHO-points" ;
                lon:units = "degree east" ;
                lon:standard name = "longitude" ;
                lon:grid mapping = "projection 1" ;
                lon:field = "lon, scalar" ;
        float temperature(time, depth, Y, X) ;
                temperature:units = "Celsius" ;
                temperature:grid = "grid" ;
                temperature:location = "face" ;
                temperature:field = "temperature, scalar, series" ;
                temperature: FillValue = 1.e+37f ;
                temperature:grid mapping = "projection 1" ;
                temperature:long name = "Sea water potential temperature";
                temperature:standard name =
"sea water potential temperature";
                temperature:time = "time" ;
                temperature:coordinates = "lon lat time" ;
```

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What does it look like?

\$ ncview mysubset.nc4

NCVIEW 2.1.6	🕲 ២ mysubset.nc4
Barents-2.5km - ROMS	
displaying Sea water potential te n perature	
frame 12/24 16-Jun-2020 11:00:00	
displayed range: -0.613486 to 4.71063 Celsius	
Current: (i=79, j=131) 2.5259 (x=-4.529926, y=71.50051)	and the
Quit ->1 (Delay: Opts	
3gauss Inv P Inv C H X3 Linear Axes Range Bi-lin Print	
Yar: lat lon temperature	
Din: Name: Min: Current: Max: Units:	
Scan: time 1.59227e+09 16-Jun-2020 1 1.59235e+09 seconds since	
Y: Y -870432 -Y517932 n	C MA
X: X 513603 -X- 711103 m	
et up to handle cases with coordinate mapping using anything oth	

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Benefits?

- OPeNDAP URL for aggregation does not change as new files enter from daily production - no need to decode filenames
- Fimex allows natural coordinates (lat/lon, depth, ISO-time) instead of indexes
- Extract just what you need (900KB from a 20GB dataset)
- Thredds makes data available everywhere, portability of data use (lustre -> thredds -> fimex -> HPC)
- Fimex can also regrid and interpolate

See https://wiki.met.no/fimex/documentation - in particular the workshop presentations











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Other solutions?

Fimex is not the only tool that can abstract OPeNDAP access, see NCKS, NCO, Perl, Python, Ruby, R, MATLAB, IDL, etc. The list of tools is growing. https://www.unidata.ucar.edu/software/netcdf/software.html

You may find anything from full GUI applications (IDV), command-line tools, to libraries that you can embed in your favourite programming language. Most certainly a toolbox is ready for you in your favourite working environment.

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Summary

- Create your data files as NetCDF, add CF Conventions to describe the content and make it easy to read.
- Expose the files through TDS, you can make aggregations and collections. You get a built-in viewer, OPeNDAP access and WMS out-of-the-box
- Use OPeNDAP-enabled tools to extract what you need and process the data
- Users are happy and the producers don't need to push data around