

CDO installation and use

Climate Modelling course
Chair of Meteorology

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Europäische Union

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Diese Maßnahme wird mitfinanziert durch Steuermittel auf der Grundlage des vom Sächsischen Landtag beschlossenen Haushaltes.

1. From the CDO documentation

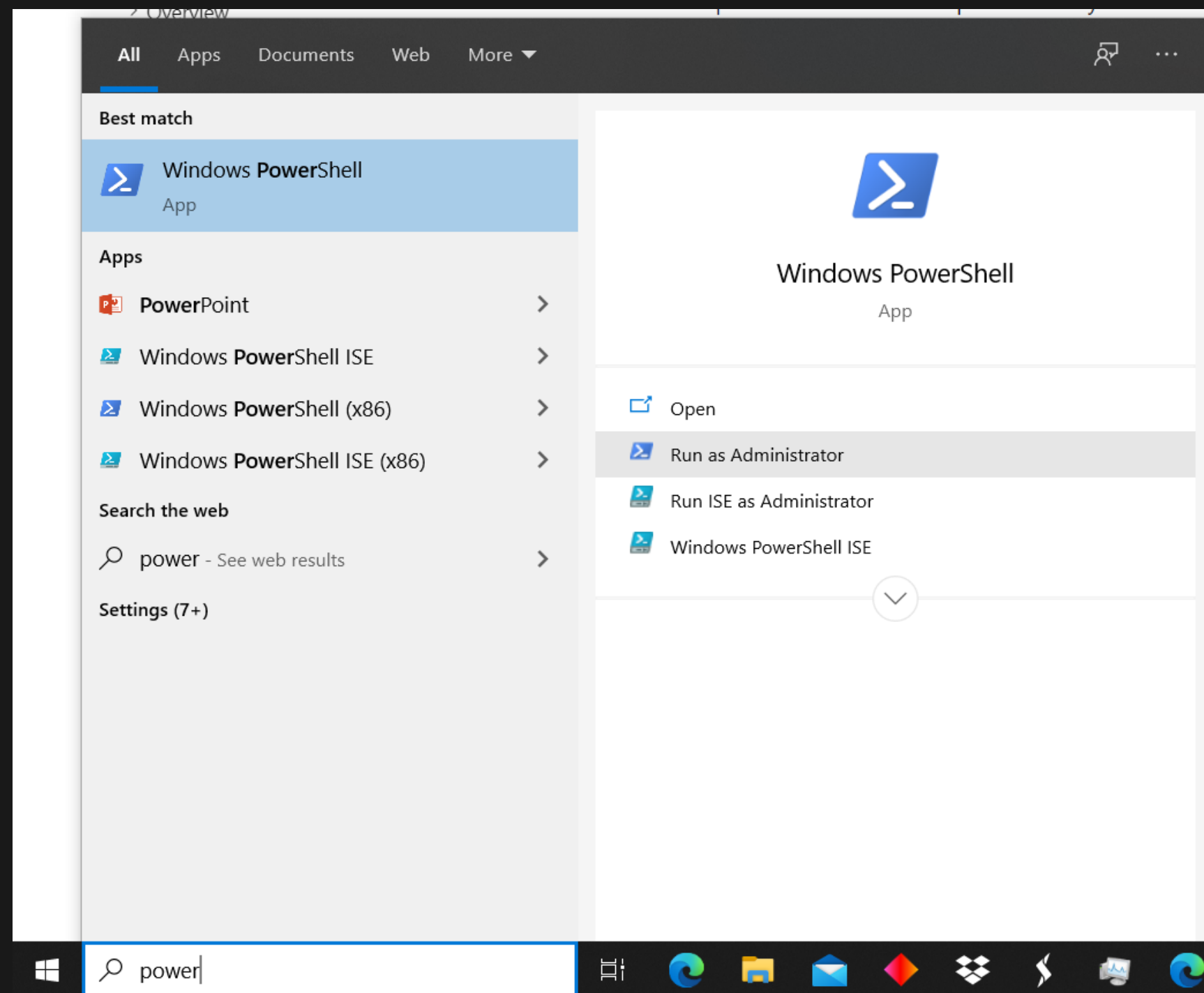
- **CDO** stands for [Climate Data Operators](#)
- CDO is [meant](#) for Posix compatible operating systems (like Linux)
- Nevertheless, [here](#) you can find the official recommendations to run *CDO on Windows*
 - The *Windows Subsystem for Linux* version 2 (wsl2) installs a Linux kernel to create a proper compatibility layer for Windows
 - The following steps correspond to option #2 on the documentation and works for *Windows 10*
 - For *Windows 8*, *ws/1* should be installed (not yet tested for our purpose)
 - *Windows S* is incompatible
- Should also work in [MacOS](#)

2. Install ws/

- **Option #1:** *Windows 10* version 2004 and higher, or *Windows 11* check [here](#)
- **Option #2:** older versions, check [here](#)
- Note that these steps are for ws/ version 2
- Some visual aid is added

2.1. Option #1:

1. Open PowerShell as Administrator:



2. Run (type or copy — paste [right-click on *PowerShell*] and then press enter):

```
wsl --install
```

! This should already install *Ubuntu* version 20.04 (?), for other versions/distros check [here](#)

! Since these changes are quite new, these steps have not been tested

2.2. Option #2

1. Open PowerShell as Administrator (as shown before)
2. Run:

```
dism.exe /online /enable-feature /featurename:  
Microsoft-Windows-Subsystem-Linux /all /norestart
```



This should be typed all together (one line)

2.3. Update to WSL 2 (check Windows version)

- Windows 10 **version 1903+**, **build 18362+**. For most computers (x64)
- Check with **Win key + R**, type **winver** → **OK**
- Update if needed:

If you are running Windows 10 version 1903 or 1909, open "Settings" from your Windows menu, navigate to "Update & Security" and select "Check for Updates". Your Build number must be 18362.1049+ or 18363.1049+, with the minor build # over .1049.

2.4. Enable Virtual Machine feature

1. From the PowerShell as Administrator run:

```
dism.exe /online /enable-feature /featurename:VirtualMachinePlatform /all /norestart
```

2. Restart to complete WSL install and updates

2.5. Download the Linux kernel update package

- [Download](#) WSL2 Linux kernel update package for x64 machines
- Install as administrator (elevated permissions)

2.6. Set WSL 2 as your default version

- From the PowerShell as Administrator run:

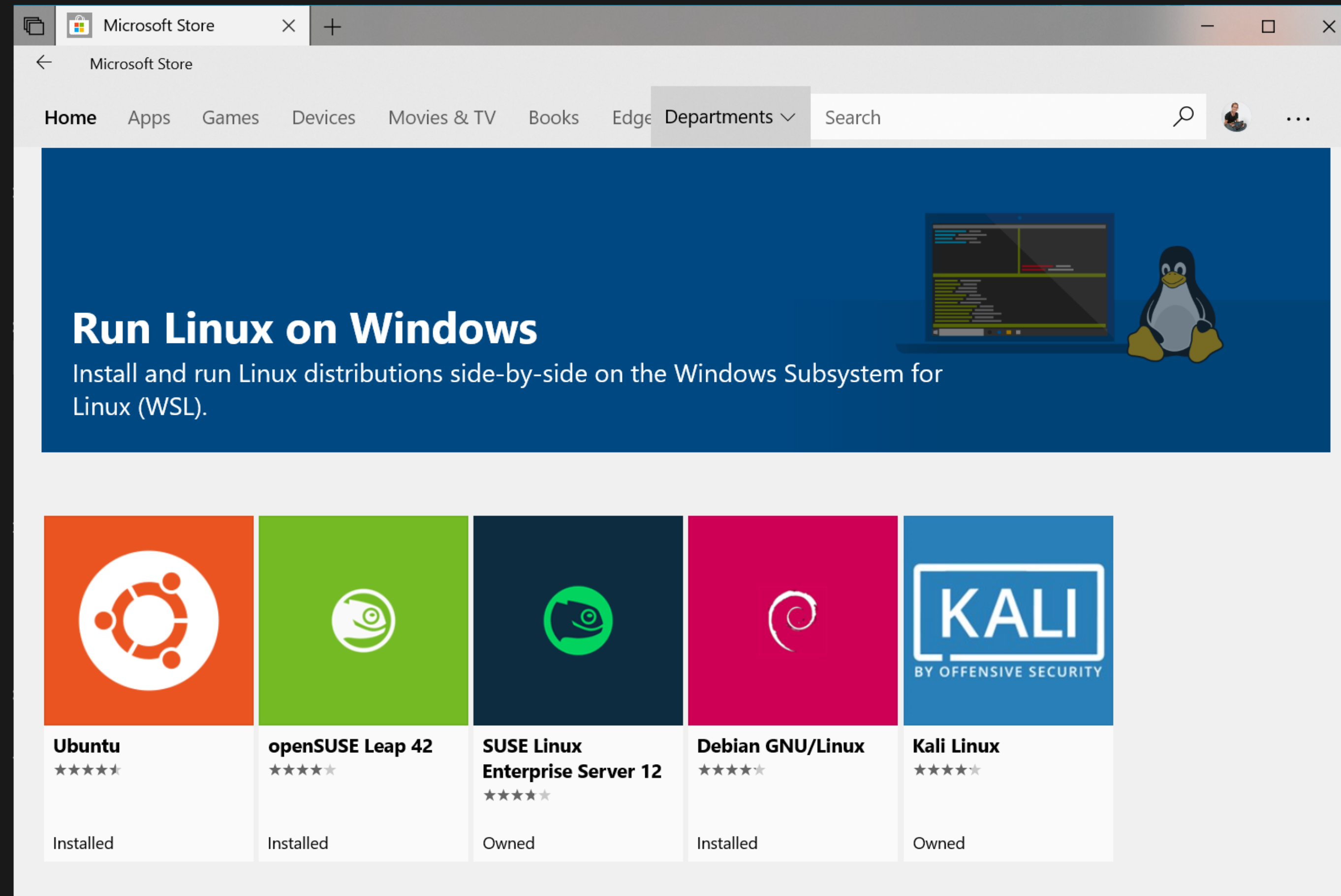
```
wsl --set-default-version 2
```



wsl2 setup finished!

2.7. Install Linux distro

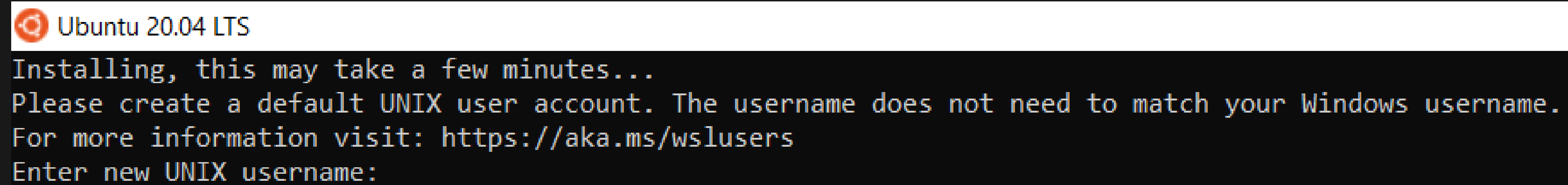
1. Open the Microsoft Store and select a Linux distribution (distro)



2. Ubuntu 18.04 and 20.04 were tested for CDO. After this, *Ubuntu* should be a searchable program in Windows

3. Setting up Ubuntu

1. Open the Ubuntu app
2. On the first launch, it will show this:



The screenshot shows a terminal window titled "Ubuntu 20.04 LTS". The text inside the terminal reads: "Installing, this may take a few minutes... Please create a default UNIX user account. The username does not need to match your Windows username. For more information visit: <https://aka.ms/wslusers> Enter new UNIX username:". The text is displayed in a monospaced font with a light blue color on a dark background.

```
Ubuntu 20.04 LTS
Installing, this may take a few minutes...
Please create a default UNIX user account. The username does not need to match your Windows username.
For more information visit: https://aka.ms/wslusers
Enter new UNIX username:
```

3. Set credentials, user and password (twice)
4. Output should look like this:

dqc@ ~

Installing, this may take a few minutes...

Please create a default UNIX user account. The username does not need to match your Windows username.

For more information visit: <https://aka.ms/wslusers>

Enter new UNIX username: dqc

New password:

Retype new password:

passwd: password updated successfully

Installation successful!

To run a command as administrator (user "root"), use "sudo <command>".

See "man sudo_root" for details.

Welcome to Ubuntu 20.04.1 LTS (GNU/Linux 4.19.128-microsoft-standard x86_64)

- * Documentation: <https://help.ubuntu.com>
- * Management: <https://landscape.canonical.com>
- * Support: <https://ubuntu.com/advantage>

System information as of Sat Oct 17 17:22:44 CEST 2020

System load:	0.1	Processes:	8
Usage of /:	0.4% of 250.98GB	Users logged in:	0
Memory usage:	0%	IPv4 address for eth0:	192.168.115.158
Swap usage:	0%		

1 update can be installed immediately.

0 of these updates are security updates.

To see these additional updates run: `apt list --upgradable`

The list of available updates is more than a week old.

To check for new updates run: `sudo apt update`

This message is shown once once a day. To disable it please create the
/home/dqc/.hushlogin file.

dqc@ ~\$

3.2. Update and upgrade

- Run from the Linux terminal:

```
sudo apt-get update  
sudo apt-get upgrade -y
```

- To run `sudo` you will be asked for the password set in the previous step
- This might take a while, you should see something like this:

```
Fetchd 17.4 MB in 4s (4629 kB/s)
Reading package lists... Done
dqc@:~$ sudo apt-get upgrade -y
Reading package lists... Done
Building dependency tree
Reading state information... Done
Calculating upgrade... Done
The following packages have been kept back:
  base-files sosreport ubuntu-server
The following packages will be upgraded:
  alsa-ucm-conf apport bcache-tools bind9-dnsutils bind9-host bind9-libs bolt bsutils busybox-initramfs busybox-st
  cryptsetup-run curl fdisk finalrd gcc-10-base gir1.2-packagekitglib-1.0 initramfs-tools initramfs-tools-bin initr
  libc-bin libc6 libcryptsetup12 libcurl3-gnutls libcurl4 libdns-export1109 libfdisk1 libgcc-s1 libgl1 libglvnd0 li
  libpam-modules-bin libpam-runtime libpam0g libproxy1v5 libpulse0 libpulsedsp libpython3.8 libpython3.8-minimal li
  locales mdadm mount open-vm-tools packagekit packagekit-tools pulseaudio-utils python3-apport python3-commandnotf
  python3-software-properties python3-urllib3 python3.8 python3.8-minimal rsyslog secureboot-db show-motd snapd sof
  ubuntu-wsl unattended-upgrades update-motd util-linux uuid-runtime xz-utils zlib1g
97 upgraded, 0 newly installed, 0 to remove and 3 not upgraded.
Need to get 55.9 MB of archives.
After this operation, 3645 kB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu focal-updates/main amd64 bsutils amd64 1:2.34-0.1ubuntu9.1 [63.1 kB]
Get:2 http://archive.ubuntu.com/ubuntu focal-updates/main amd64 gcc-10-base amd64 10.2.0-5ubuntu1~20.04 [19.7 kB]
```

4. Install and check CDO

- To install, simply run from the Ubuntu terminal:

```
sudo apt-get install cdo -y
```



Installation finished!

- The last step works also for other *Ubuntu* based distros
- It is also available for other distros, e.g. *Arch* based

4.1. CDO version

- Check that *CDO* is working with:

```
cdo --version
```

```
dqc@:/mnt/e/HSE/Thesis/Data/Taurus$ cdo --version
Climate Data Operators version 1.9.3 (http://mpimet.mpg.de/cdo)
CXX Compiler: g++ -g -O2 -fdebug-prefix-map=/build/cdo-g3Qjnd/cdo-1.9.3+dfsg.1=. -fstack-protector-strong
g -Wformat -Werror=format-security -fopenmp
CXX version : g++ (Ubuntu 7.3.0-1ubuntu1) 7.3.0
C Compiler: gcc -g -O2 -fdebug-prefix-map=/build/cdo-g3Qjnd/cdo-1.9.3+dfsg.1=. -fstack-protector-strong
-Wformat -Werror=format-security -Wall -pedantic -fPIC -fopenmp
C version : gcc (Ubuntu 7.3.0-1ubuntu1) 7.3.0
F77 Compiler: f77 -g -O2 -fdebug-prefix-map=/build/cdo-g3Qjnd/cdo-1.9.3+dfsg.1=. -fstack-protector-strong
F77 version : unknown
Features: 12GB C++14 Fortran DATA PTHREADS OpenMP45 HDF5 NC4/HDF5/threadsafe OPeNDAP SZ UDUNITS2 PROJ.4
MAGICS CURL FFTW3 SSE2
Libraries: HDF5/1.10.0 proj/4.93 curl/7.58.0
Filetypes: srv ext ieg grb1 grb2 nc1 nc2 nc4 nc4c nc5
  CDI library version : 1.9.3
GRIB_API library version : 2.6.0
  NetCDF library version : 4.6.0 of Feb  9 2018 19:21:24 $
  HDF5 library version : library undefined
  EXSE library version : 1.4.0
  FILE library version : 1.8.3
```


5. CDO installation in MacOS

- The following solutions have not been tested by us but they reportedly work for MacOS. This information was taken from the CDO [wiki](#)

1. With [MacPorts](#) simply run from the terminal:

```
port install cdo +grib_api +magicspp +szip
```

2. With [homebrew](#):

```
brew tap moffat/sciencebits  
brew install cdo
```

- If needed, to install [homebrew](#):

1. To install with [ruby](#), run this:

```
ruby -e "$(curl -fsSL https://raw.githubusercontent.com/Homebrew/install/master/install)"
```

2. If the last command doesn't work, try:

```
curl -fsSL https://raw.githubusercontent.com/Homebrew/install/master/install > \  
brew_install_script  
ruby brew_install_script  
rehash
```

6. Basic shell commands

- To work from the terminal, some basic commands are needed:

1. `mkdir` → creates directory. The following creates the folder `data` in the current directory

```
mkdir data
```

2. `pwd` → print working directory. To check the current working directory

3. `cd` → change directory. To access the created folder:

```
cd data
```

4. `ls` → list contents of current directory

5. `cp` → copy file. This copies `file1` to `file2`

```
cp file1 file2
```

6. `mv` → move files or directories (also to rename). The following moves `file1` into the created folder while renaming it to `file2`

```
mv file1 data/file2
```

7. `cat` → prints the content of a file (text)

- More info [here](#) and [here](#)

7. Accessing Windows files from Linux

1. Download the `test.nc` file ([here](#), under `nc_files`)
2. If the file was downloaded to `C:\User\Downloads`, to access the downloads folder do:

```
cd /mnt/c/User/Downloads
```

3. Try some *CDO* commands as:

```
cdo sinfo test.nc # short description of the file  
cdo griddes test.nc # grid description, output on next slide  
cdo graph,device="png" -selgridcell,1 test.nc plot # quick plot
```

4. The *CDO* operators are [here \(explained\)](#) or type:

```
cdo --operators
```

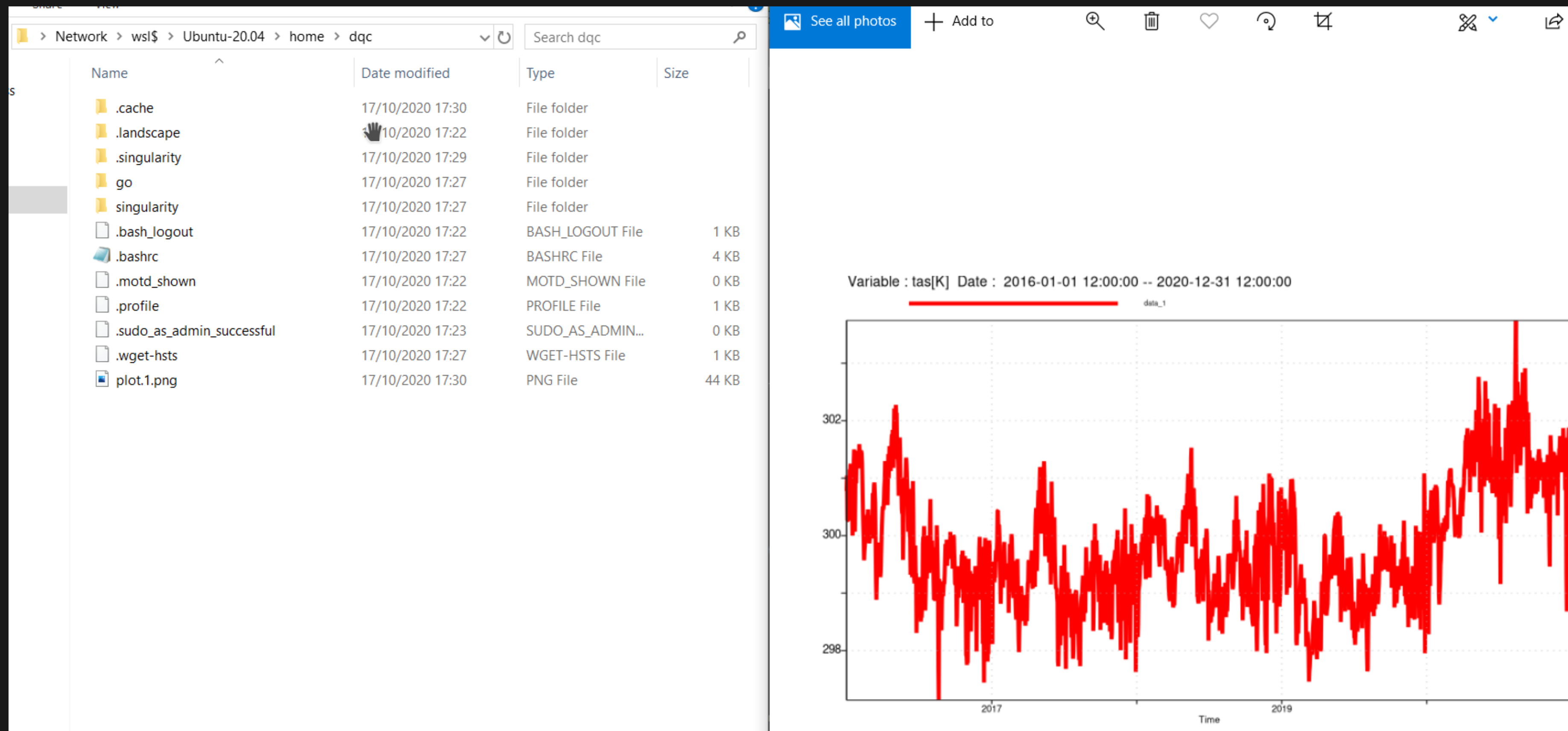
5. If you encounter issues opening or accessing the file do:

```
sudo chown $USER test.nc
```

```
dqc@ :/mnt/e/HSE/Thesis/Data/Taurus$ cdo griddes test1.nc4
#
# gridID 1
#
gridtype  = lonlat
gridsize  = 196
xsize     = 14
ysize     = 14
xname     = lon
xlongname = "longitude"
xunits    = "degrees_east"
yname     = lat
ylongname = "latitude"
yunits    = "degrees_north"
xfirst    = 270
xinc      = 0.75
yfirst    = 15
yinc      = -0.75
scanningMode = 64
cdo griddes: Processed 1 variable [0.01s 57MB]
```

8. Accessing Linux files from Windows

1. Type `\\wsl$` on the file explorer path (on the top), enter
2. Then click *Ubuntu* → *home* → *user*
3. Should look something like this (note the plot created before):



9. Exercise

1. Exploration of *NetCDF* files
2. Visualization of the files
 - A set of example files are in this [repo](#), `nc_files` folder
3. Manipulation of files
4. Selection of desired coordinates
5. Export data as text for further manipulation in other software
6. Download CORDEX files

10. Exploration

- To have an idea of the contents of the file we can run some commands from the terminal that will print some information to the screen
- Commands to try:
 - `cdo sinfo file` → short description of the contents
 - `cdo griddes file` → description of the grid
 - `ncdump file` → metadata description, not CDO but useful
 - Try with `-h` (header) and `-c` (coordinates)
- See more options with `cdo --operators`
- Check help of a operator with e.g. `cdo --help sellonlatbox` or [here](#)

11. Visualization

- It is possible to create high-quality plots from CDO by using the [Magics](#) software
 - Already included in the installation process explained before
- The documentation of the use of [CDO+Magics](#) is [here](#)
- There are 3 types of plots with this combination
 - 2D Lon-Lat plots: `shaded`, `grfill` and `contour`
 - 2D `vector` plots: plots vectors (e.g. wind fields) on 2D maps
 - Line `graph` plots: generates time-series plots
- Due to the *rotated pole* rotation embedded in **CORDEX** projections, 2D plotting options within CDO are not available
 - They only accept *rectilinear* grids and CORDEX is *curvilinear*
 - Reprojection needed to plot them
 - It can be done with CDO
 - Or check this [repo](#) for an *R* solution

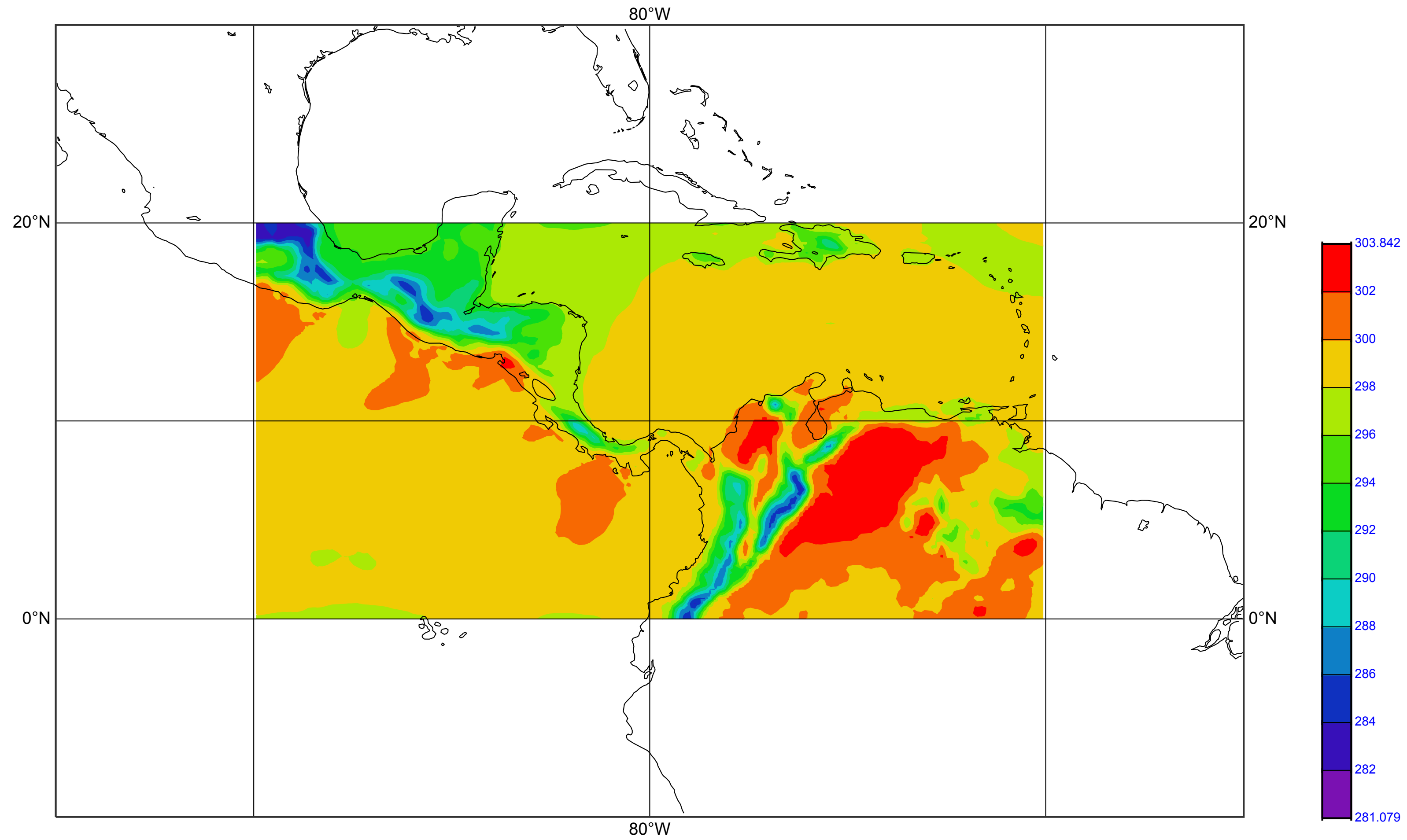
11.1. 2D Lon-Lat

- From the terminal, access the folder where the `2m_temperature.nc` file was downloaded
 - This file is a small example of a *rectangular* grid taken from ERA5
- Run the following command

```
cdo -shaded,device=pdf,lon_max=-50,lon_min=-110,lat_max=30,lat_min=-10,\
interval=2,colour_triad=cw,colour_min=violet,colour_max=red \
-seltimestep,42 2m_temperature.nc shaded
```

- Resulting file `shaded_2t.pdf` should be created, shown on next slide
- Note the arguments passed to CDO
 - Two functions, `shaded` and `seltimestep`, are passed with corresponding parameters
 - The `-` allows concatenation of several functions
 - Here we selected only the 42nd step.
 - The `\` are only to break the line, this command could be written in one line
- Try adding `,step_freq=10` after `red` (no space) and removing `-seltimestep,42`
 - Check resulting file
- Try the `contour` and `grfill` commands

2t [K] 1979-02-10 11:30:00



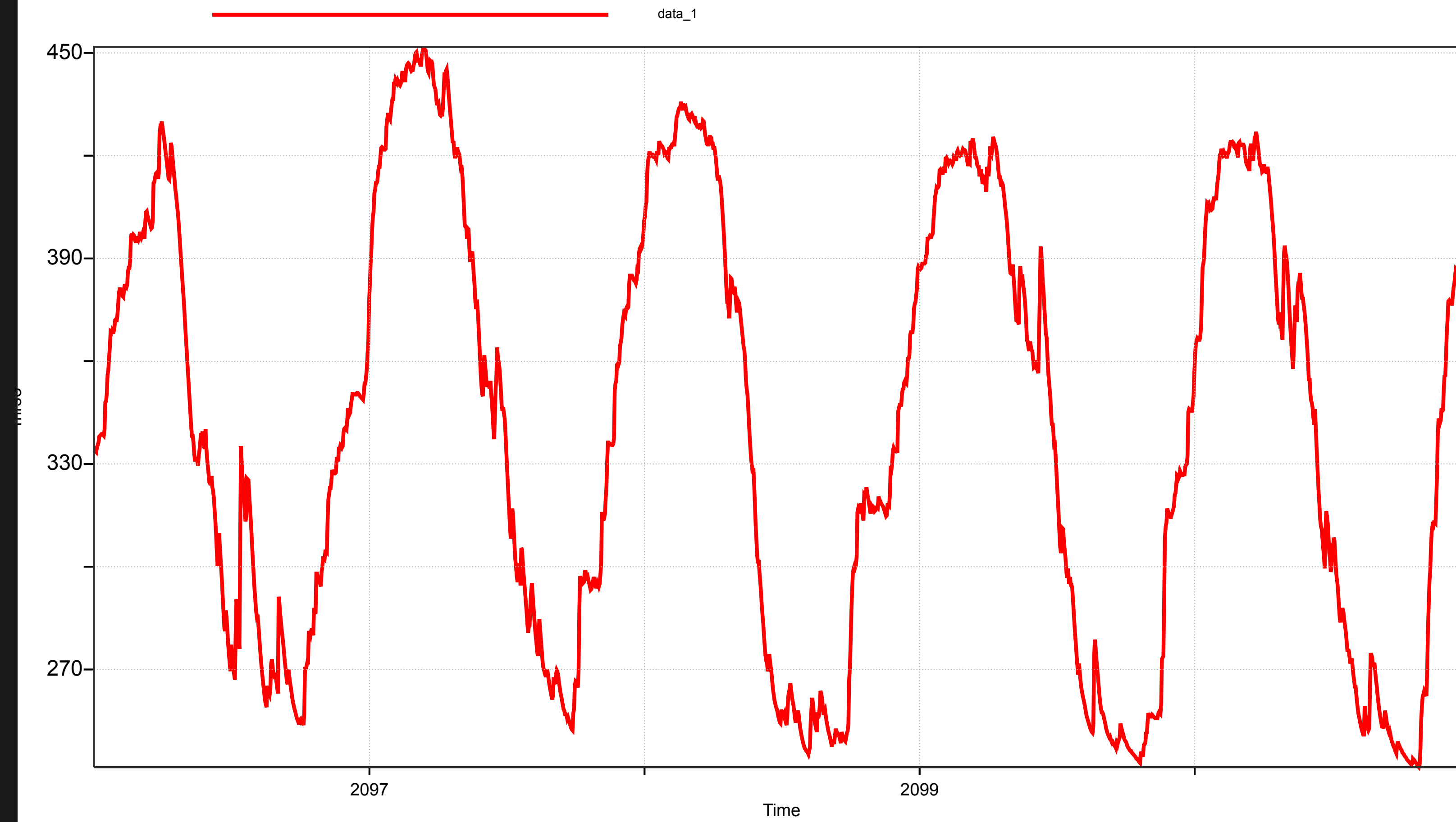
11.3. Line graph plots

- These type of plots are possible with CORDEX files (no need for rectangular grids)
- Let's plot a time series for the city of Dresden
- Run this command from the terminal:

```
cdo -graph,device=pdf,linewidth=4 -remapnn,lon=13.73/lat=51.05 \
mrso_EUR-44_ICHEC-EC-EARTH_rcp85_r12i1p1_SMHI-RCA4_v1_day_20960101-21001231.nc graph
```

- The file `graph.pdf` should have been created in the working directory
- Note the `remapnn` function → remap to the nearest neighbour
 - Returns the time series related to the pixel in which the given coordinate pair is
- Plot in next slide

Variable : mrso[kg m-2] Date : 2096-01-01 12:00:00 -- 2100-12-31 12:00:00



12. Manipulation of files

12.1. Merge

- Merge all the provided historical run files into one and save into new file

```
cdo -z zip -mergetime \  
mrso_EUR-44_ICHEC-EC-EARTH_historical_r12i1p1_SMHI-RCA4_v1_day_19* \  
historical_1961-1990.nc
```

- Notes
 - `-z zip` to compress the file
 - `-mergetime` is the main function
 - `19*` wildcard to give as input all the historical files instead of typing each
 - `historical_1961-1990.nc` is the name of the output file
- Explore resulting file

12.2. Cropping

- To select only a pixel where our location of interest is, again, for Dresden:

```
cdo -remapnn,lon=13.73/lat=51.05 \  
mrso_EUR-44_ICHEC-EC-EARTH_rcp85_r12i1p1_SMHI-RCA4_v1_day_20960101-21001231.nc \  
mrso_dresden.nc
```

- To select the pixels inside a boundary box, Saxony (approx.) for example:

```
cdo -sellonlatbox,11.5,15.5,49.7,52.2 \  
mrso_EUR-44_ICHEC-EC-EARTH_rcp85_r12i1p1_SMHI-RCA4_v1_day_20960101-21001231.nc \  
mrso_saxony.nc
```

- Check the files with `griddes` and `sinfo`

12.3. Exporting to text

- For further analysis and plots, one might want to export some information in text format
- For example, for the previous file for Dresden:

```
cdo -outputkey,year,month,day,lon,lat,value mrso_dresden.nc > table.txt
```

- The file `table.txt` will be created and can be parsed with e.g. R, Python or Excel to do:
 - Further statistical analysis
 - Boxplots comparing historical vs future conditions
 - Day of the year plots, etc.

13. Downloading CORDEX files

- 1. Create account for ESGF [node](#)
- 2. Login with your [OpenID](#) after receiving confirmation email
- 3. Register to the CORDEX group
- 4. Explore and select desired data (checked boxes, note for later, where the pointer is)

Project

☒ CORDEX (8)

Product

Domain

☒ CAM-44 (8)

Institute

Driving Model

☒ MPI-M-MPI-ESM-LR (8)

Experiment

☒ historical (4)
☒ rcp85 (4)

Experiment Family

Ensemble

RCM Model

Downscaling Realisation

Time Frequency

☒ day (8)

Variable

Variable Long Name

☒ Near-Surface Air Temperature (2)
☒ Precipitation (2)
☒ Total Runoff (2)
☒ Total Soil Moisture Content (2)

CF Standard Name

Datanode

Enter Text:

?

Search

Reset

Display

10

▼

results per page

[More Search Options]

☐ Show All Replicas

☐ Show All Versions

☐ Search Local Node Only (Including All Replicas)

Search Constraints:

☒ CAM-44

|

☒ CORDEX

|

☒ historical,rcp85

|

☒ day

|

☒ Near-Surface Air Temperature,Precipitation,Total Runoff,Total Soil Moisture Content

|

☒ MPI-M-MPI-ESM-LR

Total Number of Results: 8

-1-

Add all displayed results to Data Cart

Remove all displayed results from Data Cart

Expert Users: you may display the search URL and return results as XML or return results as JSON

1. cordex.output.CAM-44.SMHI.MPI-M-MPI-ESM-LR.historical.r1i1p1.RCA4.v1.day.mrso

Data Node: esg-dn1.nsc.liu.se

Version: 20141105

Total Number of Files (for all variables): 11

Full Dataset Services: [Show Metadata] [List Files] [THREDDS Catalog] [WGET Script]

Add to Data Cart

2. cordex.output.CAM-44.SMHI.MPI-M-MPI-ESM-LR.historical.r1i1p1.RCA4.v1.day.mrro

Data Node: esg-dn1.nsc.liu.se

Version: 20141105

Total Number of Files (for all variables): 11

Full Dataset Services: [Show Metadata] [List Files] [THREDDS Catalog] [WGET Script]

Add to Data Cart

3. cordex.output.CAM-44.SMHI.MPI-M-MPI-ESM-LR.historical.r1i1p1.RCA4.v1.day.pr

Data Node: esg-dn1.nsc.liu.se

Version: 20141105

Total Number of Files (for all variables): 11

Full Dataset Services: [Show Metadata] [List Files] [THREDDS Catalog] [WGET Script]

Add to Data Cart

4. cordex.output.CAM-44.SMHI.MPI-M-MPI-ESM-LR.historical.r1i1p1.RCA4.v1.day.tas

Data Node: esg-dn1.nsc.liu.se

Version: 20141105

Total Number of Files (for all variables): 11

Full Dataset Services: [Show Metadata] [List Files] [THREDDS Catalog] [WGET Script]

Add to Data Cart

5. cordex.output.CAM-44.SMHI.MPI-M-MPI-ESM-LR.rcp85.r1i1p1.RCA4.v1.day.mrso

Data Node: esg-dn1.nsc.liu.se

Version: 20141105

Total Number of Files (for all variables): 19

Full Dataset Services: [Show Metadata] [List Files] [THREDDS Catalog] [WGET Script]

Add to Data Cart

13.1. File by file

- 1. To download file by file through your browser click on `list files`
- 2. Then click on `HTTP Download`, this will open a prompt

1. **cordex.output.CAM-44.SMHI.MPI-M-MPI-ESM-LR.historical.r1i1p1.RCA4.v1.day.mrso**
Data Node: `esg-dn1.nsc.liu.se`
Version: 20141105
Total Number of Files (for all variables): 11
Full Dataset Services: [[Show Metadata](#)] [[Hide Files](#)] [[THREDDS Catalog](#)] [[WGET Script](#)]

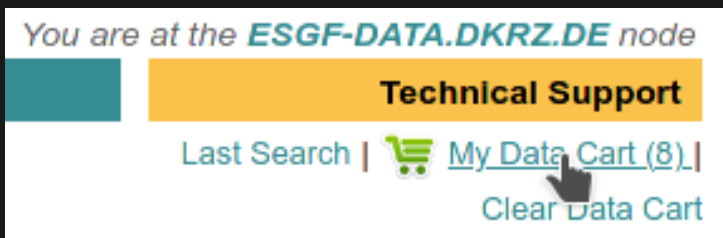
Total Number of Files: 11

1	mrso_CAM-44_MPI-M-MPI-ESM-LR_historical_r1i1p1_SMHI-RCA4_v1_day_19510101-19551231.nc checksum: <code>f4d8a4d4765f2d223fba8363de8b9b9e94fb381012b6044601d50f7bdfefbdf1f</code> size: 37739270 tracking_id: <code>d9260c16-9ad2-43d9-9f0b-8d8f844f5546</code> [More File Metadata]	Single File Access: HTTP Download OpenDAP Download
2	mrso_CAM-44_MPI-M-MPI-ESM-LR_historical_r1i1p1_SMHI-RCA4_v1_day_19560101-19601231.nc checksum: <code>31ece25e10fc0d792e1ab8a65d5374429bf91b5c7d68f36baaa5181b116a116d</code> size: 37689982 tracking_id: <code>90e9c48b-6b23-4981-b604-4ca1f8b2e5f4</code> [More File Metadata]	Single File Access: HTTP Download OpenDAP Download
3	mrso_CAM-44_MPI-M-MPI-ESM-LR_historical_r1i1p1_SMHI-RCA4_v1_day_19610101-19651231.nc checksum: <code>14ec240b7c5d512c31980f5012878d3246cde526a242d80397091f4d648d741f</code> size: 37747450 tracking_id: <code>417fb167-0055-490d-8c83-228bd63f4056</code> [More File Metadata]	Single File Access: HTTP Download OpenDAP Download

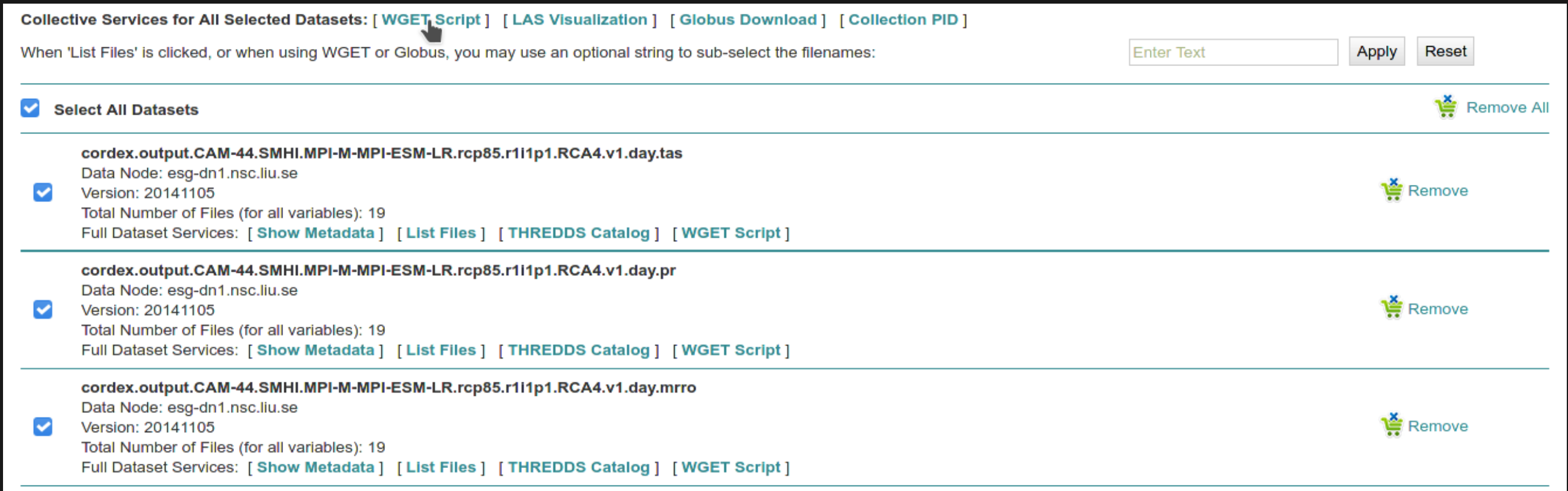
- 3. Save file and repeat
- 4. Note that CORDEX files are usually on a 5 years basis (daily)

13.2. The automated way

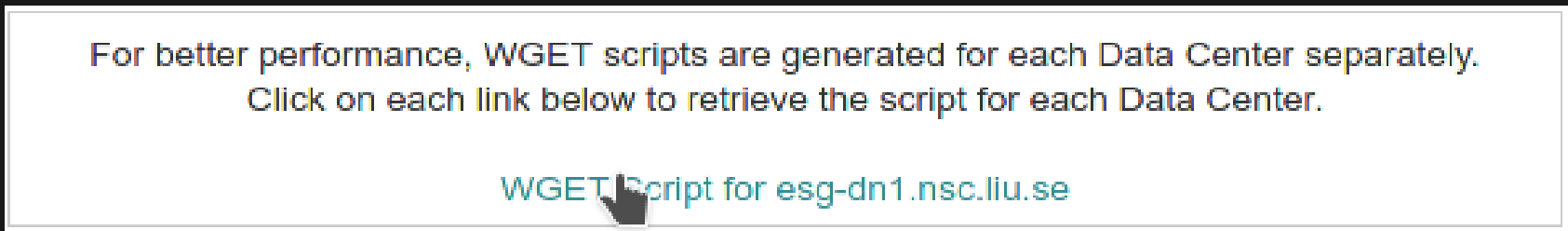
- 1. Click on **Add all displayed results to Data Cart** (where the pointer was in the penultimate image)
- 2. Go to your **data cart**



- 3. Select datasets to download. When ready, click on **WGET Script**



- 4. Depending on your dataset, there might be several **WGET Scripts**. Click and save them.



13.3. Run script

14. Homework

1. Download CORDEX files for your home region

- If not available, choose Lisbon or Delft, check [here](#) for domains
- Historical period: 1961-1990
- Projected: RCP 8.5 2070-2100
- Variables: temperature, precipitation and either run off or soil moisture content

2. Merge and crop files for your country and city

3. Perform statistical analysis for the 3 variables in another software

- Box plots of historical vs projected for your city

4. Plot time series for your home city

- Both periods and all variables

5. Extra points for:

- Probability density function plot for both periods
- Average *Day of the year* (1-365) comparison plot
- Monthly comparison boxplots
- 2D map of average difference between the periods in your home country
 - Tips: `sellatlonbox`, [this repo](#), or reprojection with CDO (`remapbil`)

15. Questions — ideas for the extra points?

💡 You can contact [me!](#)