

Analyzing and Visualizing Open Precipitation Data

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Introduction

Public Data: Many public databases have been created for the purposes of making data freely accessible to the scientific community. A best practice is to assign a unique identifier to a dataset, so that it is discoverable. A common form of a unique identifier is a [Digital Object Identifier or DOI®](#) which points to the data.

Access Public Data: To access and process public data, you can use several routes.

- Download data files to your local machine and work with them in MATLAB®.
- Access data directly via an API. MATLAB's function that [import data from NetCDF files](#) from RESTful API used by many portals.

- If the portal offers only Python® bindings, [call Python from MATLAB](#).

Data formats: MATLAB supports a broad range of data formats

- There is a wide range of scientific data formats that can be [natively read in MATLAB](#). They include NetCDF, HDF5 and GRIB as well as more specialized data formats.
- In addition, the [Mapping Toolbox™](#) contains [built-in functions](#) to read data from many online data repositories in standard geo-data formats.
- Sometimes data import functions may be [written by the Geoscience community](#), and published on the MATLAB [File Exchange](#) - a portal for community contributions in MATLAB. All community contributions are covered by open source licenses, which means they can be re-used, modified or added to. Exact terms and conditions depend on the licenses used by the author.

Data and Resources

In this example, we use data covered by permissive license, (i.e., the [Creative Commons Attribution 4.0 International License](#) - CC BY 4.0). It is important for Open Science to have such data since under CC BY 4.0 license you are free to share, copy, redistribute and adapt the material as long as you give appropriate credit, provide a link to the license, and indicate if any changes were made.

We access global climate data from the WCRP CMIP6 (World Climate Research Programme Coupled Intercomparison Project - Phase 6), which are located at: <https://esgf-data.dkrz.de/search/cmip6\~dkrz/>.

The Data Space is hosted by the [German Climate Computer Center](#) (DKRZ) and the [Infrastructure for the European Network for Earth System Modelling](#) (IS-ENES), as a part of the global [Earth System Grid Federation](#) (ESGF).

The user can apply multiple filters and preferences for a large variety of climate parameters, such as sea ice thickness, air pressure, phytoplankton mass concentration, etc, provided by different sources. In our example we used the following filtering:

- CF Standard name: precipitation flux
- Frequency: day
- Nominal Resolution: 10km, 25km

Make sure to check the box "Show all Replicas".

Example links for the data from [ESGF MetaGrid](#) ([Inl.gov](#)):

- data [Link](#) (1950 - 2014); e.g., [data 19530101-19531231](#)
- data [Link](#) (2015 - 2050); e.g., [data 20450101-20451231](#)

Data Acknowledgment Statement (see [CMIP6 terms of use](#)):

"We acknowledge the World Climate Research Programme, which, through its Working Group on Coupled Modelling, coordinated and promoted CMIP6. We thank the climate modeling groups for producing and making available their model output, the Earth System Grid Federation (ESGF) for archiving the data and providing access, and the multiple funding agencies who support CMIP6 and ESGF. We used the CMIP6 model data produced by the Research Center for Environmental Changes, Academia Sinica, Taiwan (AS-RCEC), which is licensed under a Creative

Further information about this data can be found via the `further_info_url` (recorded as a "Global Attributes: License" in these .nc files). The data producers and data providers make no warranty, either express or implied, including, but not limited to, warranties of merchantability and fitness for a particular purpose. All liabilities arising from the supply of the information (including any liability arising in negligence) are excluded to the fullest extent permitted by law."

Import Data from the web

```
In [1]: clearvars; clc; close all
```

You can read any 2 data sets from the [example links](#) indicated above, one imported as "URLpast" and a subsequent one as "URLproj".

There are a bunch of [functions that you can use to interact with NetCDF files](#).

```
In [2]: % read NETCDF data from the web
        URLpast = "https://esgf-data1.llnl.gov/thredds/dodsC/css03_data/CMIP6/HighResMIP/AS-RC
        URLproj = "https://esgf-data1.llnl.gov/thredds/dodsC/css03_data/CMIP6/HighResMIP/AS-RC
```

Read the precipitation flux as "Variable"

```
In [3]: ncdisp(URLpast)
        ncdisp(URLproj)
        Variable = "pr";
```

Source:

https://esgf-data1.llnl.gov/thredds/dodsC/css03_data/CMIP6/HighResMIP/AS-RCE C/HiRAM-SIT-HR/highresSST-present/r1i1p1f1/day/pr/gn/v20210713/pr_day_HiRAM-SIT-HR_highresSST-present_r1i1p1f1_gn_19530101-19531231.nc

Format:

classic

Global Attributes:

Conventions	= 'CF-1.7 CMIP-6.2'
activity_id	= 'HighResMIP'
branch_method	= 'no parent'
contact	= 'Dr. Chia-Ying Tu (cytu@gate.sinica.edu.tw)'
creation_date	= '2021-07-01T18:11:53Z'
data_specs_version	= '01.00.32'
experiment	= 'forced atmosphere experiment for 1950-2014'
experiment_id	= 'highresSST-present'
external_variables	= 'areacella'
forcing_index	= 1
frequency	= 'day'
further_info_url	= 'https://furtherinfo.es-doc.org/CMIP6.AS-RCE C.HiRAM-SIT-HR.highresSST-present.none.r1i1p1f1'
grid	= 'primarily 0.25deg; 1536 x 768 longitude/latitude'
grid_label	= 'gn'
history	= '2021-07-01T18:11:53Z ; CMOR rewrote data to be consistent with CMIP6, CF-1.7 CMIP-6.2 and CF standards.'
initialization_index	= 1
institution	= 'Research Center for Environmental Changes, Academia Sinica, Nankang, Taipei 11529, Taiwan'

```

institution_id      = 'AS-RCEC'
mip_era              = 'CMIP6'
nominal_resolution  = '25 km'
parent_activity_id   = 'no parent'
parent_experiment_id = 'no parent'
parent_mip_era       = 'no parent'
parent_source_id     = 'no parent'
parent_time_units    = 'no parent'
parent_variant_label = 'no parent'
physics_index        = 1
product              = 'model-output'
realization_index    = 1
realm                = 'atmos'
source               = 'HiRAM-SIT-HR (2018):
                        aerosol: none
                        atmos: GFDL-HiRAM (Cubed-sphere (c384) - 0.2
5 degree nominal horizontal resolution; 1536 x 768 longitude/latitude; 32 levels; top le
vel 1 hPa)

                        atmosChem: none
                        land: GFDL-LM3 (same grid as atmos)
                        landIce: none
                        ocean: SIT (1-D, tripolar - nominal 0.25 de
g; 1440 x 1080 longitude/latitude; 50 levels with skin layer and 1 m resolution for uppe
rmost 10 m)

                        ocnBgchem: none
                        seaIce: none'
source_id            = 'HiRAM-SIT-HR'
source_type          = 'AGCM AER'
sub_experiment       = 'none'
sub_experiment_id    = 'none'
table_id             = 'day'
table_info           = 'Creation Date:(28 May 2020) MD5:7d39246ef10
34245efba3e04f5c9ac59'
title                = 'HiRAM-SIT-HR output prepared for CMIP6'
variable_id          = 'pr'
variant_label        = 'r1i1p1f1'
license              = 'CMIP6 model data produced by REQUIRED is li
censed under a Creative Commons Attribution ShareAlike 4.0 International License (http
s://creativecommons.org/licenses). Consult https://pcmdi.llnl.gov/CMIP6/TermsOfUse for t
erms of use governing CMIP6 output, including citation requirements and proper acknowle
dgment. Further information about this data, including some limitations, can be found via
the further_info_url (recorded as a global attribute in this file) and. The data produce
rs and data providers make no warranty, either express or implied, including, but not li
mited to, warranties of merchantability and fitness for a particular purpose. All liabil
ities arising from the supply of the information (including any liability arising in negl
igence) are excluded to the fullest extent permitted by law.'
cmor_version         = '3.5.0'
tracking_id          = 'hdl:21.14100/708b6a19-2ace-4e8f-b90c-23e3dc
fc050f'
DODS_EXTRA.Unlimited_Dimension = 'time'
Dimensions:
  time = 365      (UNLIMITED)
  bnds = 2
  lat  = 768
  lon  = 1536
Variables:
  time
    Size:          365x1
    Dimensions:    time
    Datatype:      double
    Attributes:
      bounds       = 'time_bnds'
      units        = 'days since 1948-1-1 00:00:00'
      calendar     = 'standard'
      axis         = 'T'
      long_name    = 'time'

```

```

standard_name = 'time'
_chunkSizes   = 1

time_bnds
  Size:          2x365
  Dimensions:    bnds,time
  Datatype:      double
  Attributes:
    _ChunkSizes = [1  2]

lat
  Size:          768x1
  Dimensions:    lat
  Datatype:      double
  Attributes:
    bounds       = 'lat_bnds'
    units        = 'degrees_north'
    axis         = 'Y'
    long_name     = 'Latitude'
    standard_name = 'latitude'

lat_bnds
  Size:          2x768
  Dimensions:    bnds,lat
  Datatype:      double
  Attributes:
    _ChunkSizes = [768  2]

lon
  Size:          1536x1
  Dimensions:    lon
  Datatype:      double
  Attributes:
    bounds       = 'lon_bnds'
    units        = 'degrees_east'
    axis         = 'X'
    long_name     = 'Longitude'
    standard_name = 'longitude'

lon_bnds
  Size:          2x1536
  Dimensions:    bnds,lon
  Datatype:      double
  Attributes:
    _ChunkSizes = [1536  2]

pr
  Size:          1536x768x365
  Dimensions:    lon,lat,time
  Datatype:      single
  Attributes:
    standard_name = 'precipitation_flux'
    long_name     = 'Precipitation'
    comment       = 'includes both liquid and solid phases'
    units         = 'kg m-2 s-1'
    original_name = 'precip'
    original_units = 'kg/m2/s'
    history       = '2021-07-01T18:11:53Z altered by CMOR: Converted
units from 'kg/m2/s' to 'kg m-2 s-1'.'
    cell_methods  = 'area: time: mean'
    cell_measures = 'area: areacella'
    missing_value = 1.000000020040877e+20
    _FillValue    = 1.000000020040877e+20
    _ChunkSizes   = [1  384  768]

Source:
  https://esgf-data1.llnl.gov/thredds/dodsC/css03_data/CMIP6/HighResMIP/AS-RCE
C/HiRAM-SIT-HR/highresSST-future/r1i1p1f1/day/pr/gn/v20210707/pr_day_HiRAM-SIT-HR_highre
sSST-future_r1i1p1f1_gn_20450101-20451231.nc
Format:
  classic
Global Attributes:
  Conventions = 'CF-1.7 CMIP-6.2'

```

```

        activity_id = 'HighResMIP'
        branch_method = 'standard'
        branch_time_in_child = 24472
        branch_time_in_parent = 24472
        contact = 'Dr. Chia-Ying Tu (cytu@gate.sinica.edu.tw)'
        creation_date = '2021-06-29T11:29:22Z'
        data_specs_version = '01.00.32'
        experiment = 'forced atmosphere experiment for 2015-2050
using SST/sea-ice derived from CMIP5 RCP8.5 simulations and a scenario as close to RCP8.
5 as possible within CMIP6'
        experiment_id = 'highresSST-future'
        external_variables = 'areacella'
        forcing_index = 1
        frequency = 'day'
        further_info_url = 'https://furtherinfo.es-doc.org/CMIP6.AS-RCE
C.HiRAM-SIT-HR.highresSST-future.none.r11plf1'
        grid = 'primarily 0.25deg; 1536 x 768 longitude/lat
itude'
        grid_label = 'gn'
        history = '2021-06-29T11:29:22Z ; CMOR rewrote data to
be consistent with CMIP6, CF-1.7 CMIP-6.2 and CF standards.'
        initialization_index = 1
        institution = 'Research Center for Environmental Changes,
Academia Sinica, Nankang, Taipei 11529, Taiwan'
        institution_id = 'AS-RCEC'
        mip_era = 'CMIP6'
        nominal_resolution = '25 km'
        parent_activity_id = 'HighResMIP'
        parent_experiment_id = 'highresSST-present'
        parent_mip_era = 'CMIP6'
        parent_source_id = 'HiRAM-SIT-HR'
        parent_time_units = 'days since 1948-01-01 00:00:00'
        parent_variant_label = 'r11plf1'
        physics_index = 1
        product = 'model-output'
        realization_index = 1
        realm = 'atmos'
        source = 'HiRAM-SIT-HR (2018):
                    aerosol: none
                    atmos: GFDL-HiRAM (Cubed-sphere (c384) - 0.2
5 degree nominal horizontal resolution; 1536 x 768 longitude/latitude; 32 levels; top le
vel 1 hPa)
                    atmosChem: none
                    land: GFDL-LM3 (same grid as atmos)
                    landIce: none
                    ocean: SIT (1-D, tripolar - nominal 0.25 de
g; 1440 x 1080 longitude/latitude; 50 levels with skin layer and 1 m resolution for uppe
rmost 10 m)
                    ocnBgchem: none
                    seaIce: none'
        source_id = 'HiRAM-SIT-HR'
        source_type = 'AGCM AER'
        sub_experiment = 'none'
        sub_experiment_id = 'none'
        table_id = 'day'
        table_info = 'Creation Date:(28 May 2020) MD5:7d39246ef10
34245efba3e04f5c9ac59'
        title = 'HiRAM-SIT-HR output prepared for CMIP6'
        variable_id = 'pr'
        variant_label = 'r11plf1'
        license = 'CMIP6 model data produced by REQUIRED is li
censed under a Creative Commons Attribution ShareAlike 4.0 International License (http
s://creativecommons.org/licenses). Consult https://pcmdi.llnl.gov/CMIP6/TermsOfUse for t
erms of use governing CMIP6 output, including citation requirements and proper acknowl
gment. Further information about this data, including some limitations, can be found via
the further_info_url (recorded as a global attribute in this file) and. The data produce

```

rs and data providers make no warranty, either express or implied, including, but not limited to, warranties of merchantability and fitness for a particular purpose. All liabilities arising from the supply of the information (including any liability arising in negligence) are excluded to the fullest extent permitted by law.'

```
cmor_version      = '3.5.0'
tracking_id       = 'hdl:21.14100/bc166568-c398-40fb-9db3-391252
149fdf'
```

```
DODS_EXTRA.Unlimited_Dimension = 'time'
```

Dimensions:

```
time = 365      (UNLIMITED)
bnds = 2
lat  = 768
lon  = 1536
```

Variables:

time

```
Size:      365x1
Dimensions: time
Datatype:  double
Attributes:
    bounds      = 'time_bnds'
    units       = 'days since 1948-1-1 00:00:00'
    calendar    = 'standard'
    axis        = 'T'
    long_name    = 'time'
    standard_name = 'time'
    _ChunkSizes = 1
```

time_bnds

```
Size:      2x365
Dimensions: bnds,time
Datatype:  double
Attributes:
    _ChunkSizes = [1  2]
```

lat

```
Size:      768x1
Dimensions: lat
Datatype:  double
Attributes:
    bounds      = 'lat_bnds'
    units       = 'degrees_north'
    axis        = 'Y'
    long_name    = 'Latitude'
    standard_name = 'latitude'
```

lat_bnds

```
Size:      2x768
Dimensions: bnds,lat
Datatype:  double
Attributes:
    _ChunkSizes = [768  2]
```

lon

```
Size:      1536x1
Dimensions: lon
Datatype:  double
Attributes:
    bounds      = 'lon_bnds'
    units       = 'degrees_east'
    axis        = 'X'
    long_name    = 'Longitude'
    standard_name = 'longitude'
```

lon_bnds

```
Size:      2x1536
Dimensions: bnds,lon
Datatype:  double
Attributes:
    _ChunkSizes = [1536  2]
```

pr

```
Size:      1536x768x365
```

```

Dimensions: lon,lat,time
Datatype:   single
Attributes:
            standard_name = 'precipitation_flux'
            long_name     = 'Precipitation'
            comment       = 'includes both liquid and solid phases'
            units         = 'kg m-2 s-1'
            original_name = 'precip'
            original_units = 'kg/m2/s'
            history       = '2021-06-29T11:29:22Z altered by CMOR: Converted
units from 'kg/m2/s' to 'kg m-2 s-1'.'
            cell_methods  = 'area: time: mean'
            cell_measures = 'area: areacella'
            missing_value = 1.000000020040877e+20
            _FillValue    = 1.000000020040877e+20
            _ChunkSizes   = [1 384 768]

```

Read and filter Geospatial Data

read longitude and latitude from the .nc file

```

In [4]: lon = double(ncread(URLpast,'lon'));
        lat = double(ncread(URLpast,'lat'));

```

Filter Data in Time and Space

Select boundaries of a rectangular area

```

In [5]: %minimum and maximum longitude
        minlon = 25;maxlon = 40; % set values from 0 to 360
        %minimum and maximum latitude
        minlat = 35;maxlat = 50; % set values from -90 to 90

```

Select first day and number of days after the first (*their sum must not exceed 365*)

```

In [6]: starttime = 100;counttime = 190;% set values from 1 to 365

```

Find the indexes of longitude and latitude that correspond to the selected geographical boundaries

```

In [7]: indlon = find(lon>=minlon & lon<=maxlon);
        indlat = find(lat>=minlat & lat<=maxlat);

        startlon=indlon(1);countlon=numel(indlon);
        startlat=indlat(1);countlat=numel(indlat);

```

Import Filtered Data

Import longitude, latitude, time and precipitation values for past and future data, as constrained in the [previous section](#).

```

In [8]: lat = double(ncread(URLpast,'lat',startlat,countlat));
        lon = double(ncread(URLpast,'lon',startlon,countlon));
        tpast = double(ncread(URLpast,'time',starttime,counttime));
        tproj = double(ncread(URLproj,'time',starttime,counttime));

```



```
Varpast = double(ncread(URLpast,Variable,[startlon startlat starttime],[countlon countla  
Varproj = double(ncread(URLproj,Variable,[startlon startlat starttime],[countlon countla
```

read the precipitation unit from the .nc file

```
In [9]: unit = ncreadatt(URLpast,'pr','original_units');
```

Convert units from sec-1 to day-1

```
In [10]: Varpast = Varpast*86400;  
Varproj = Varproj*86400;  
newunit = "kg m^-^2 day^-^1"
```

```
Out[10]: newunit = "kg m^-^2 day^-^1"
```

Calculate dates

calculate date vectors, as days passed since the reference date in the .nc file

```
In [11]: Tpast = datetime('1948-1-1')+tpast,Tproj = datetime('1948-1-1')+tproj  
Tpast.Format = 'dd-MMM-uuuu';Tproj.Format = 'dd-MMM-uuuu';  
Tpast_str = string(Tpast);  
Tproj_str = string(Tproj);
```

```
Out[11]: Tpast = 190x1 datetime array  
10-Apr-1953 12:00:00  
11-Apr-1953 12:00:00  
12-Apr-1953 12:00:00  
13-Apr-1953 12:00:00  
14-Apr-1953 12:00:00  
15-Apr-1953 12:00:00  
16-Apr-1953 12:00:00  
17-Apr-1953 12:00:00  
18-Apr-1953 12:00:00  
19-Apr-1953 12:00:00  
20-Apr-1953 12:00:00  
21-Apr-1953 12:00:00  
22-Apr-1953 12:00:00  
23-Apr-1953 12:00:00  
24-Apr-1953 12:00:00  
25-Apr-1953 12:00:00  
26-Apr-1953 12:00:00  
27-Apr-1953 12:00:00  
28-Apr-1953 12:00:00  
29-Apr-1953 12:00:00  
30-Apr-1953 12:00:00  
01-May-1953 12:00:00  
02-May-1953 12:00:00  
03-May-1953 12:00:00  
04-May-1953 12:00:00  
05-May-1953 12:00:00  
06-May-1953 12:00:00  
07-May-1953 12:00:00  
08-May-1953 12:00:00  
09-May-1953 12:00:00
```

```
Out[11]: Tproj = 190x1 datetime array
```

```
10-Apr-2045 12:00:00
11-Apr-2045 12:00:00
12-Apr-2045 12:00:00
13-Apr-2045 12:00:00
14-Apr-2045 12:00:00
15-Apr-2045 12:00:00
16-Apr-2045 12:00:00
17-Apr-2045 12:00:00
18-Apr-2045 12:00:00
19-Apr-2045 12:00:00
20-Apr-2045 12:00:00
21-Apr-2045 12:00:00
22-Apr-2045 12:00:00
23-Apr-2045 12:00:00
24-Apr-2045 12:00:00
25-Apr-2045 12:00:00
26-Apr-2045 12:00:00
27-Apr-2045 12:00:00
28-Apr-2045 12:00:00
29-Apr-2045 12:00:00
30-Apr-2045 12:00:00
01-May-2045 12:00:00
02-May-2045 12:00:00
03-May-2045 12:00:00
04-May-2045 12:00:00
05-May-2045 12:00:00
06-May-2045 12:00:00
07-May-2045 12:00:00
08-May-2045 12:00:00
09-May-2045 12:00:00
```

Select a day to visualize precipitation data

```
In [12]: close all
```

Select a day

```
In [13]: t1 = Tpast_str(6);inx = Tpast_str == t1;
```

Create a grid with precipitation values

```
In [14]: [lat1,lon1] = meshgrid(lat,lon);
Varlpast = Varpast(:,:,inx);
Varlproj = Varproj(:,:,inx);
mV = min([min(Varlpast(:)),min(Varlproj(:))])
MV = max([max(Varlpast(:)),max(Varlproj(:))])
```

```
Out[14]: mV = -9.0042e-16
```

```
Out[14]: MV = 51.4354
```

Customize colormap limits to the selected data

```
In [15]: CBmin = -9.00419266706534e-16;
         CBmax = 51.43537279218435;
```

Visualize and compare past and projected data

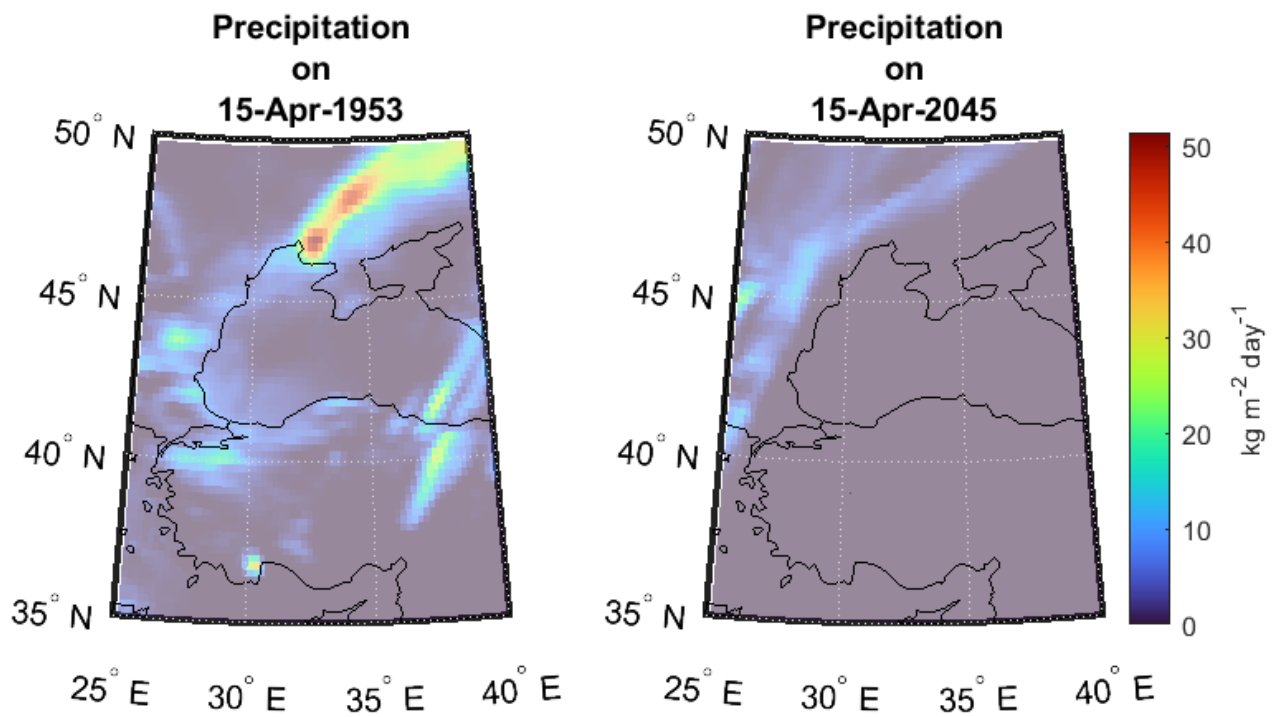
Create a 2 frame figure. Plot the past data in the left frame and the projected data in the right frame. Add the coastlines in both figures. The text displayed in the figure (title, colorbar) is also directly imported from the .nc file metadata and the parameter values we have set.

```
In [16]: tiledlayout(1,2)
nexttile % past
worldmap([minlat maxlat],[minlon maxlon])
geoshow(lat1,lon1,Varlpast,'DisplayType','texturemap','FaceAlpha',0.5);
geoshow('landareas.shp','EdgeColor','black','FaceColor','none')
title([ncreadatt(URLpast,Variable,'long_name'),'on',t1])
clim([CBmin CBmax])

nexttile %projection
worldmap([minlat maxlat],[minlon maxlon])
geoshow(lat1,lon1,Varlproj,'DisplayType','texturemap','FaceAlpha',0.5);
geoshow('landareas.shp','EdgeColor','black','FaceColor','none')
cb = colorbar; % display colorbar
cb.Location='eastoutside';
cb.Label.String = (newunit);
title([ncreadatt(URLproj,Variable,'long_name'),'on',Tproj_str(inx)])
clim([CBmin CBmax])

colormap turbo
```

Out[16]:



Some Stats!

In this section a comparison is performed between the past and projected data.

- First, the precipitation time series (daily, solid lines; cumulative, dashed lines) are plotted in the same plot for direct comparison.
- Then, [box charts](#) are generated to show the daily sum average precipitation values distribution (including the outliers)
- Finally, 3 Hypothesis Tests are performed to evaluate the statistical significance of the results from the comparison of the past and projected precipitation:
 - a) The [Wilcoxon rank sum test](#): Tests the null hypothesis that past and projected data are samples from continuous distributions with equal medians, against the alternative that they are not.
 - b) The [2 sample t-test](#): Tests the null hypothesis that past and projected data come from independent random samples from normal distributions with equal means and equal but unknown variances. The alternative hypothesis is that the past and projected data comes from populations with unequal means.
 - c) The 2 sample [Kolmogorov - Smirnov test](#): Tests the null hypothesis that that past and projected data are from the same continuous distribution against the alternative hypothesis that they are from different continuous distributions.

Compare incremental and cumulative precipitation

```
In [17]: N = numel(tpast)
```

```
Out[17]: N = 190
```

Select number of days (between 1 and N)

```
In [18]: T1 = Tpast_str(1);inx1 = Tpast_str == T1;n1 = find(inx1);  
T2 = Tpast_str(190);inx2 = Tpast_str == T2;n2 = find(inx2);  
n = n2 - n1 +1;  
if n2<=n1;error('End date (n2) should be greater than start date (n1)');end
```

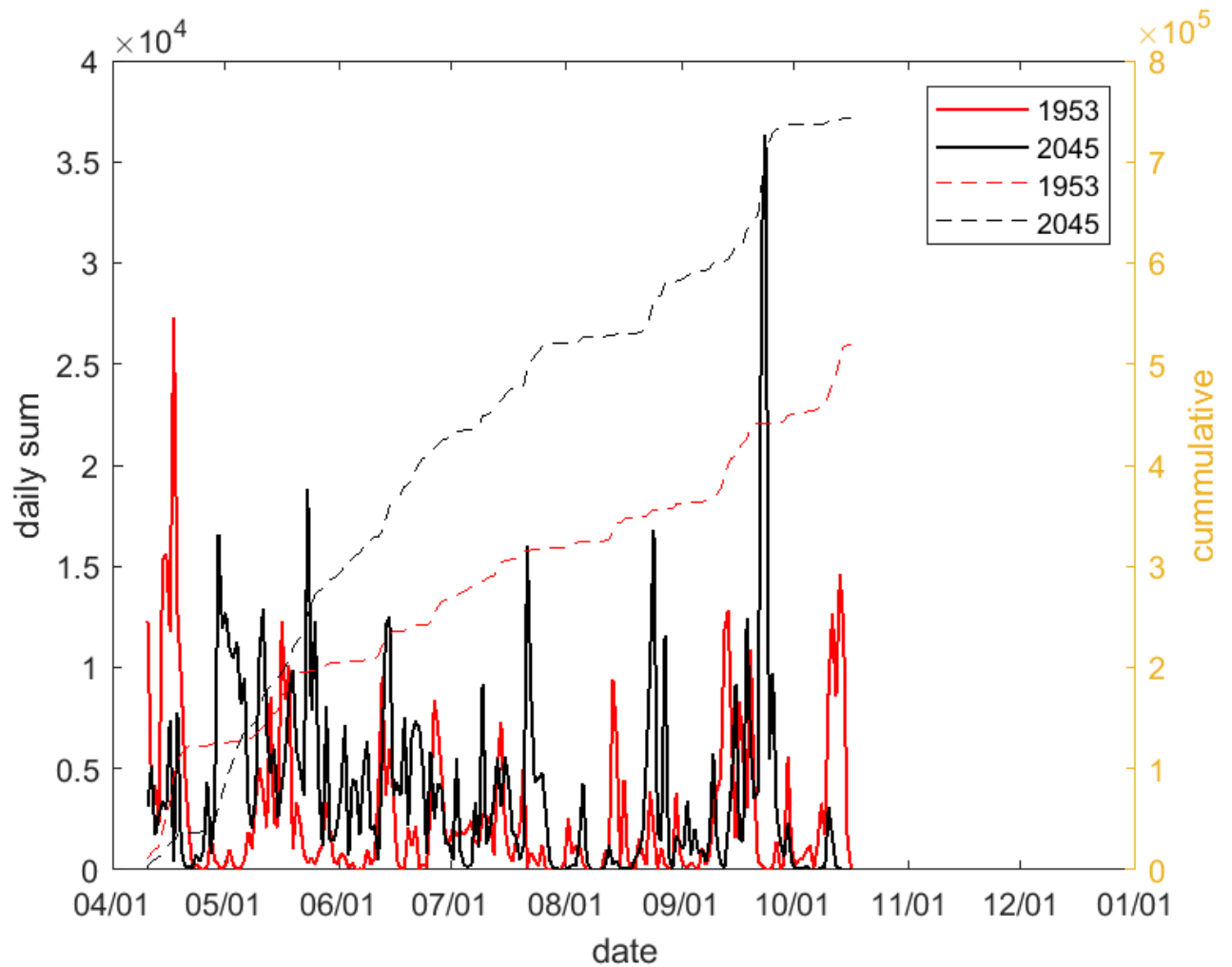
Generate Daily/Cumulative Plots and Box Charts

```
In [19]: Boxp1 = zeros(size(n,1));Boxp2 = zeros(size(n,1));cou=1;  
for i=n1:n2  
Boxp1(cou) = sum(Varpast(:, :, i), "all");  
Boxp2(cou) = sum(Varproj(:, :, i), "all");  
cou=cou+1;  
end
```

Daily and Cumulative plots

```
In [20]: figure  
plot(Tpast(n1:n2),Boxp1,'r-',Tpast(n1:n2),Boxp2,'k-',LineWidth=1);datetick('x',6);ylabel  
hold on  
yyaxis right;plot(Tpast(n1:n2),cumsum(Boxp1),'r-',Tpast(n1:n2),cumsum(Boxp2),'k-');dat  
legend(num2str(year(Tpast(1))),num2str(year(Tproj(1))),num2str(year(Tpast(1))),num2str(y
```

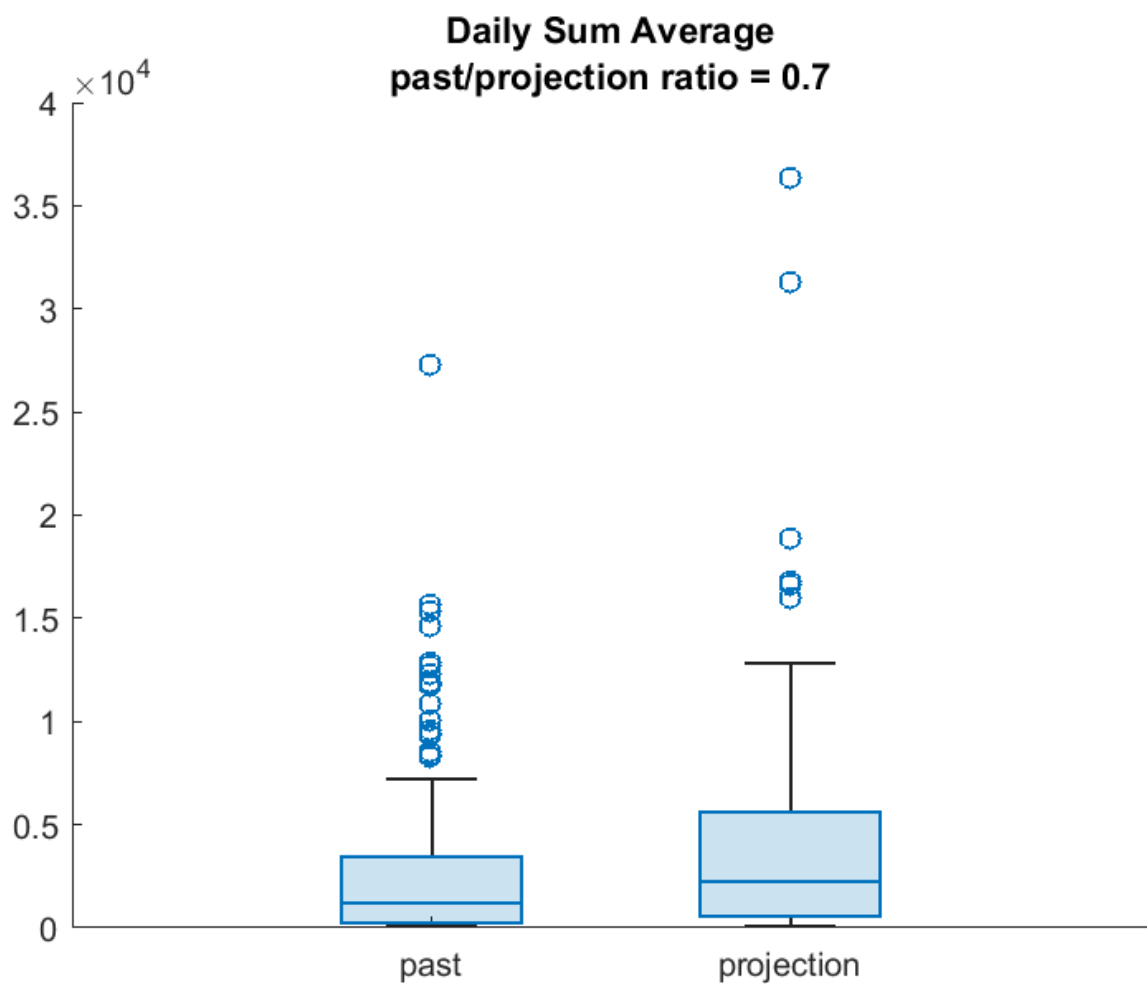
```
Out[20]:
```



Box charts

```
In [21]: figure
group = categorical([ repmat("past", size(Boxp1)); repmat("projection", size(Boxp2))]);
boxchart([Boxp1',Boxp2']);xticklabels({'past','projection'});
title(["Daily Sum Average","past/projection ratio = "+num2str(sum(Boxp1)/sum(Boxp2),'%7.
```

Out[21]:



Perform Statistical Tests

```
In [22]: [p.Wilcoxon,h.Wilcoxon] = ranksum(Boxp1,Boxp2); % null hypothesis, h0, equal medians
[h.ttest2,p.ttest2] = ttest2(Boxp1,Boxp2); % null hypothesis, h0, equal means
[h.kstest2,p.kstest2] = kstest2(Boxp1,Boxp2); % null hypothesis, h0, samples come from t
h.ttest2 = logical(h.ttest2);
```

```
if h.Wilcoxon==0;disp(['>> The <strong>Wilcoxon</strong> rank sum test FAILS to reject t
else; disp(['>> The <strong>Wilcoxon</strong> rank sum test REJECTS the hypothesis of eq
end
```

```
>> The <strong>Wilcoxon</strong> rank sum test REJECTS the hypothesis of equal medians a
t 0.0017175 significance
```

```
In [23]: if h.ttest2==0;disp(['>> The 2-sample <strong>t-test</strong> FAILS to reject the hypoth
else; disp(['>> The 2-sample <strong>t-test</strong> REJECTS the hypothesis of equal mea
end
```

```
>> The 2-sample <strong>t-test</strong> REJECTS the hypothesis of equal means at 0.01160
2 significance
```

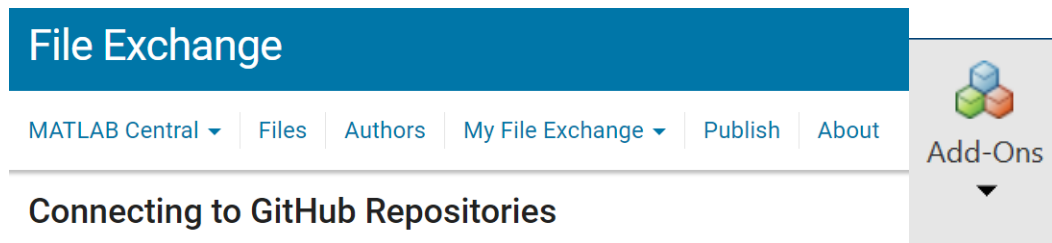
```
In [24]: if h.kstest2==0;disp(['>> The 2-sample <strong>Kolmogorov-Smirnov</strong> test FAILS to
else; disp(['>> The 2-sample <strong>Kolmogorov-Smirnov</strong> test REJECTS the hypoth
end
```

```
>> The 2-sample <strong>Kolmogorov-Smirnov</strong> test REJECTS the hypothesis that the
two samples come from the same distribution at 0.0038639 significance
```

Publish reusable MATLAB code for reproducible results

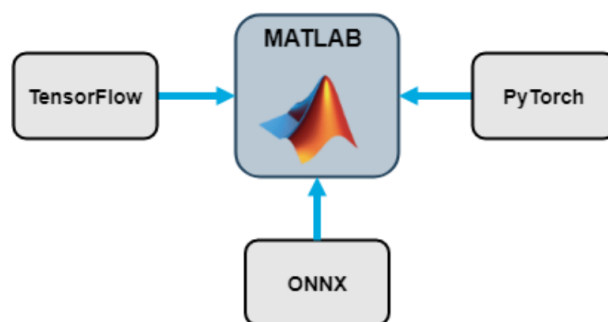
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- [Link your GitHub repository to File Exchange](#) to make your MATLAB code available to MATLAB users via the Add-Ons button.

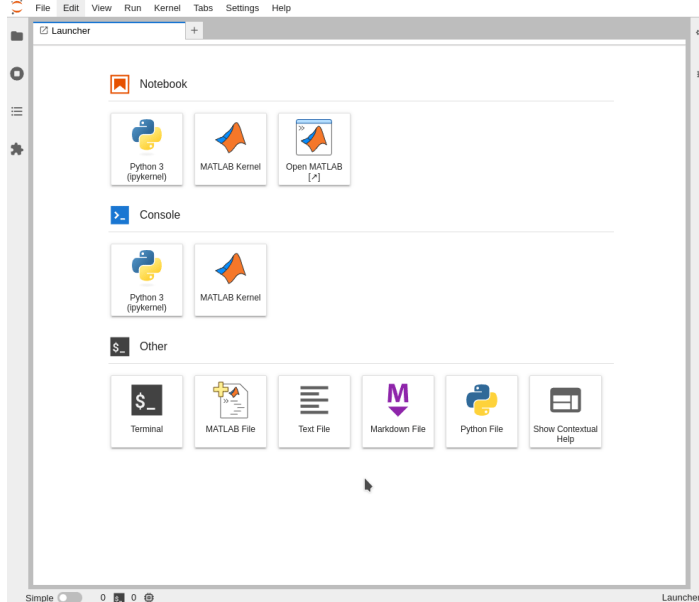


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Functions that Import Deep Learning Networks



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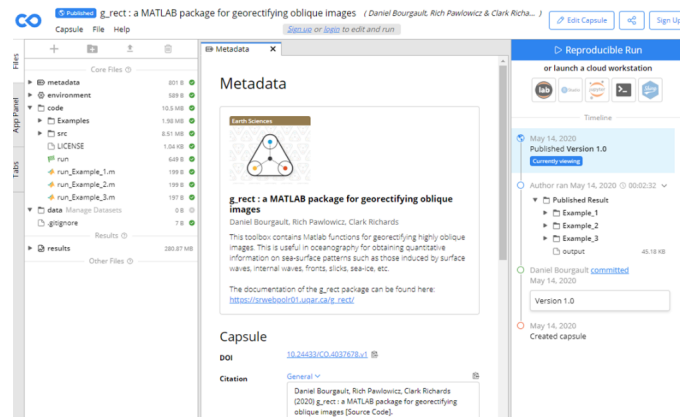
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