

prcp_rcp85

July 19, 2022

```
[1]: import cartopy.crs as ccrs # for geographic plotting
import cartopy.feature as cfeature
from IPython.display import Image
import xarray as xr
import xclim as xc
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import seaborn as sns
import xclim as xc
import xarray as xr
from matplotlib.cm import get_cmap
```

```
[2]: #pr_file = '/lhome/cra2022/climriskdata/EUR-11/
↳MPI-M-MPI-ESM-LR_MPI-CSC-REMO2009_v1/historical/pr/
↳pr_EUR-11_MPI-M-MPI-ESM-LR_historical_r1i1p1_MPI-CSC-REMO2009_v1_day_19710101-20001231_LL.
↳nc'

pr_file85 = '/lhome/cra2022/climriskdata/EUR-11/
↳ICHEC-EC-EARTH_CLMcom-CCLM4-8-17_v1/rcp85/pr/
↳pr_EUR-11_ICHEC-EC-EARTH_rcp85_r12i1p1_CLMcom-CCLM4-8-17_v1_day_20710101-21001231_LL.
↳nc'

ds_pr85 = xr.open_dataset(pr_file85)

ds_pr85
```

```
[2]: <xarray.Dataset>
Dimensions:      (time: 10957, bnds: 2, lon: 471, lat: 409)
Coordinates:
  * time          (time) datetime64[ns] 2071-01-01T12:00:00 ... 2100-12-31T12:00:00
  * lon           (lon) float64 -10.0 -9.9 -9.8 -9.7 -9.6 ... 36.7 36.8 36.9 37.0
  * lat           (lat) float64 30.0 30.1 30.2 30.3 30.4 ... 70.5 70.6 70.7 70.8
Dimensions without coordinates: bnds
Data variables:
  time_bnds      (time, bnds) datetime64[ns] ...
  pr             (time, lat, lon) float32 ...
Attributes:      (12/31)
```

```

CDI:                Climate Data Interface version ?? (http:/...
history:            Tue Dec 03 10:30:57 2019: cdo mergetime /...
source:             CLMcom-CCLM4-8-17
institution:        Climate Limited-area Modelling Community ...
Conventions:        CF-1.4
institute_id:       CLMcom
...
project_id:         CORDEX
table_id:           Table day (Sept 2013) 0cf1782745489246c9f...
modeling_realm:     atmos
realization:        12
cmor_version:       2.9.1
CDO:               Climate Data Operators version 1.9.3 (htt...

```

```

[3]: pr_mm85 = ds_pr85.pr * 86400
pr_mm85.attrs['units'] = 'mm/day'
prcp_5100 = pr_mm85.sel(lat=slice(30,45))

prcp_5100

```

```

[3]: <xarray.DataArray 'pr' (time: 10957, lat: 151, lon: 471)>
array([[[[0.00000000e+00, 0.00000000e+00, 0.00000000e+00, ...,
          0.00000000e+00, 0.00000000e+00, 0.00000000e+00],
        [0.00000000e+00, 0.00000000e+00, 0.00000000e+00, ...,
          0.00000000e+00, 0.00000000e+00, 0.00000000e+00],
        [0.00000000e+00, 0.00000000e+00, 0.00000000e+00, ...,
          0.00000000e+00, 0.00000000e+00, 0.00000000e+00],
        [0.00000000e+00, 0.00000000e+00, 0.00000000e+00, ...,
          0.00000000e+00, 0.00000000e+00, 0.00000000e+00],
        ...,
        [4.58087154e+00, 4.66340133e+00, 4.75866114e+00, ...,
          1.57400972e-04, 8.65499488e-09, 2.93000144e-06],
        [5.07882165e+00, 5.18690294e+00, 5.31569172e+00, ...,
          3.21696027e-04, 1.49748271e-04, 6.74958761e-05],
        [5.39499186e+00, 5.59919765e+00, 5.80406981e+00, ...,
          1.79213920e-03, 2.17911577e-03, 2.66167458e-03]],

        [[0.00000000e+00, 0.00000000e+00, 0.00000000e+00, ...,
          2.41641056e-13, 1.14221484e-12, 2.12594463e-12],
        [0.00000000e+00, 0.00000000e+00, 0.00000000e+00, ...,
          1.26848245e-13, 6.62693786e-13, 2.23473326e-12],
        [0.00000000e+00, 0.00000000e+00, 0.00000000e+00, ...,
          7.22030197e-14, 5.00660833e-13, 2.10102888e-12],
        ...,
        [5.85345158e+00, 5.97859612e+00, 6.10708378e+00, ...,
          0.00000000e+00, 0.00000000e+00, 0.00000000e+00],
        [6.19079133e+00, 6.31659154e+00, 6.48008455e+00, ...,
          0.00000000e+00, 0.00000000e+00, 0.00000000e+00],
        [6.87905957e+00, 6.99148353e+00, 7.04229986e+00, ...,

```

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0.00000000e+00, 0.00000000e+00, 3.55507717e-13]],
[[0.00000000e+00, 0.00000000e+00, 0.00000000e+00, ...,
  0.00000000e+00, 0.00000000e+00, 0.00000000e+00],
[0.00000000e+00, 0.00000000e+00, 0.00000000e+00, ...,
  0.00000000e+00, 0.00000000e+00, 0.00000000e+00],
[0.00000000e+00, 0.00000000e+00, 0.00000000e+00, ...,
  0.00000000e+00, 0.00000000e+00, 0.00000000e+00],
...,
[9.29662026e+00, 9.74456468e+00, 1.02938124e+01, ...,
  2.90550626e-12, 1.36965047e-11, 8.21057669e-11],
[9.09370256e+00, 9.60159623e+00, 1.01997787e+01, ...,
  9.14595060e-11, 3.56561301e-10, 4.04371629e-10],
[9.20332717e+00, 9.66297376e+00, 1.02254185e+01, ...,
  3.49331233e-10, 2.14124314e-09, 1.83997821e-08]]])
Coordinates:
  * time      (time) datetime64[ns] 2071-01-01T12:00:00 ... 2100-12-31T12:00:00
  * lon       (lon) float64 -10.0 -9.9 -9.8 -9.7 -9.6 ... 36.7 36.8 36.9 37.0
  * lat       (lat) float64 30.0 30.1 30.2 30.3 30.4 ... 44.6 44.7 44.8 44.9 45.0
Attributes:
  units:      mm/day

```

```
[4]: mon_prcp_5100= prcp_5100.resample(time = 'M').sum()
```

```
mon_clim_rcp85 = mon_prcp_5100.groupby('time.month')
```

```
mon_mean_clim_rcp85 = mon_clim_rcp85.mean('time')
```

```
#mon_prcp_9120
```

```
[5]: season_prcp_7100_rcp85 = mon_prcp_5100.groupby('time.season')
```

```
season_mean_prcp_7100_rcp85 = season_prcp_7100_rcp85.sum('time')/30
```

```
season_var_prcp_7100_rcp85 = season_mean_prcp_7100_rcp85.var('season')
```

```
[6]: season_DJF_prcp_7100_rcp85 = season_mean_prcp_7100_rcp85.sel(season='DJF')
```

```
season_JJA_prcp_7100_rcp85 = season_mean_prcp_7100_rcp85.sel(season='JJA')
```

```
[7]: clim_prcp_5100 = mon_prcp_5100.sum('time')/30
```

```
clim_prcp_5100
```

```
[7]: <xarray.DataArray 'pr' (lat: 151, lon: 471)>
```

```
array([[ 38.66058969,  41.54528622,  45.68805863, ...,  26.86778304,
         26.91537706,  26.9178144 ],
       [ 39.13883754,  43.2487986 ,  47.75325954, ...,  28.53254324,
```

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        28.40322048, 28.03005011],
[ 40.12653396, 44.9273699 , 49.67215509, ..., 28.72575469,
 28.88700217, 28.98471464],
...,
[744.47096226, 753.25280835, 760.53267305, ..., 369.76726673,
 378.37859472, 389.39842952],
[743.53041703, 751.71047371, 755.13132807, ..., 371.68483173,
 381.08312349, 392.21717084],
[742.84201324, 749.05413331, 751.43550568, ..., 376.30936587,
 386.65845566, 397.66071675]])
Coordinates:
  * lon      (lon) float64 -10.0 -9.9 -9.8 -9.7 -9.6 ... 36.7 36.8 36.9 37.0
  * lat      (lat) float64 30.0 30.1 30.2 30.3 30.4 ... 44.6 44.7 44.8 44.9 45.0

```

```

[8]: del ds_pr85
     del prcp_5100

```

```

[9]: ds_pop = xr.open_dataset('/lhome/cra2022/climriskdata/EUR-11S/
    ↪Estimated_population/Estimated_population_2093_LL.nc').sel(lat=slice(30,45))
    #ds_pop_medi = ds_pop.sel(lat=slice(30,45))

    ds_pop

```

```

[9]: <xarray.Dataset>
Dimensions:      (lon: 471, lat: 151)
Coordinates:
  * lon          (lon) float64 -10.0 -9.9 -9.8 -9.7 -9.6 ... 36.7 36.8 36.9 37.0
  * lat          (lat) float64 30.0 30.1 30.2 30.3 30.4 ... 44.7 44.8 44.9 45.0
Data variables:
  population     (lat, lon) float32 ...
Attributes:
  CDI:           Climate Data Interface version 1.6.4 (http://code.zmaw.de/p...
  Conventions:   CF-1.4
  history:       Wed Feb 13 17:30:06 2019: cdo mul tmp1.nc Land_Surface_Mask...
  created_by:    R, packages ncdf and raster (version 2.0-12)
  date:          2012-11-08 14:48:18
  CD0:           Climate Data Operators version 1.6.4 (http://code.zmaw.de/p...

```

```

[10]: col_map = get_cmap("turbo_r").copy()
      col_map.set_under("white")
      precip_levels = np.arange(100,1200,200.)

      fig = plt.figure(figsize=(30,10))
      ax = plt.axes(projection=ccrs.PlateCarree())

      #Include a ready-to-use colormap with cmap=<colormap_name>

```

```

a = clim_prctp_5100.plot.contourf(ax=ax, transform=ccrs.PlateCarree(),
    cmap=col_map, levels = precip_levels, add_colorbar=False)
d = ds_pop.population.plot.contourf(ax=ax, transform=ccrs.
    PlateCarree(), levels=[0,500000], colors='none', hatches=['', '+++'],
    add_colorbar=False)

# Hatch color has to be changed afterwards has edgecolor
d.collections[1].set_edgecolor('Black')

# Add a contour for clarity
ds_pop.population.plot.contour(ax=ax, transform=ccrs.PlateCarree(),
    levels=[500000], colors = 'Black', linewidths=1, add_colorbar=False)

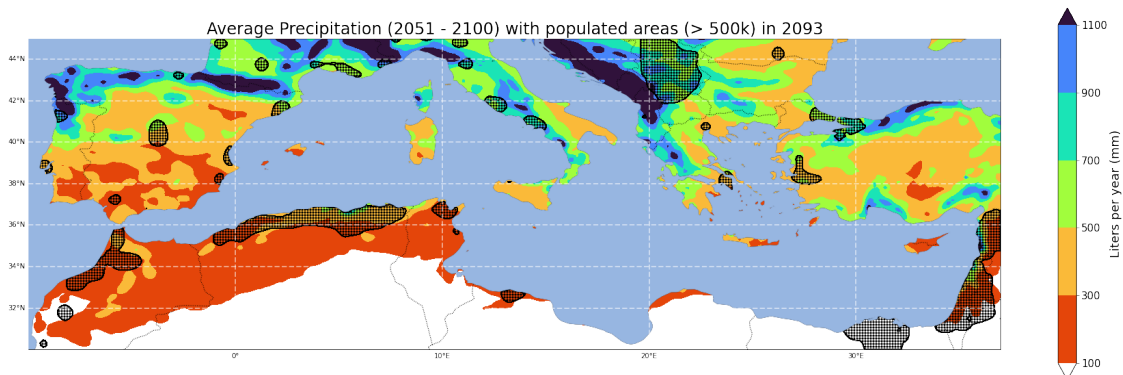
ax.add_feature(cfeature.COASTLINE, linestyle='-')
ax.add_feature(cfeature.BORDERS, linestyle=':');
ax.add_feature(cfeature.OCEAN, zorder=10)

cbar = fig.colorbar(a, ax=ax, fraction = 0.1, label=r'liters per year (mm)')
cbar.ax.tick_params(labelsize=15)
cbar.set_label("Liters per year (mm)", size=18)

gl = ax.gridlines(crs=ccrs.PlateCarree(), draw_labels=True,
    linewidth=2, color='white', alpha=0.5, linestyle='--',
    zorder=11)
gl.top_labels = False # suppress gridline labels on the top
gl.right_labels = False # suppress gridline labels at the right edge

ax.set_title('')
#ax.set_title('Time:{}'.format(nice_time), loc='right');
ax.set_title('Average Precipitation (2051 - 2100) with populated areas (> 500k)
    in 2093', fontsize=24)
plt.savefig("/lhome/cra2022/l.quirino.2_2022/Quirino_Leonardo/Project/
    Precip7100_Pop_2093_rcp85.png", dpi = 300, bbox_inches="tight", pad_inches=0)

```



```

[11]: plt.close()

[12]: col_map = get_cmap("Greens").copy()
col_map.set_under("white")
precip_levels = np.arange(25,500,75.)

fig = plt.figure(figsize=(30,10))
ax = plt.axes(projection=ccrs.PlateCarree())

#Include a ready-to-use colormap with cmap=<colormap_name>
a = season_DJF_prpcp_7100_rcp85.plot.contourf(ax=ax, transform=ccrs.
    ↪PlateCarree(), cmap=col_map, levels = precip_levels, add_colorbar=False)
d = ds_pop.population.plot.contourf(ax=ax, transform=ccrs.
    ↪PlateCarree(), levels=[0,500000], colors='none', hatches=['', '+++'], ↪
    ↪add_colorbar=False)

# Hatch color has to be changed afterwards has edgecolor
d.collections[1].set_edgecolor('Black')

# Add a contour for clarity
ds_pop.population.plot.contour(ax=ax, transform=ccrs.PlateCarree(), ↪
    ↪levels=[500000], colors = 'Black', linewidths=1, add_colorbar=False)

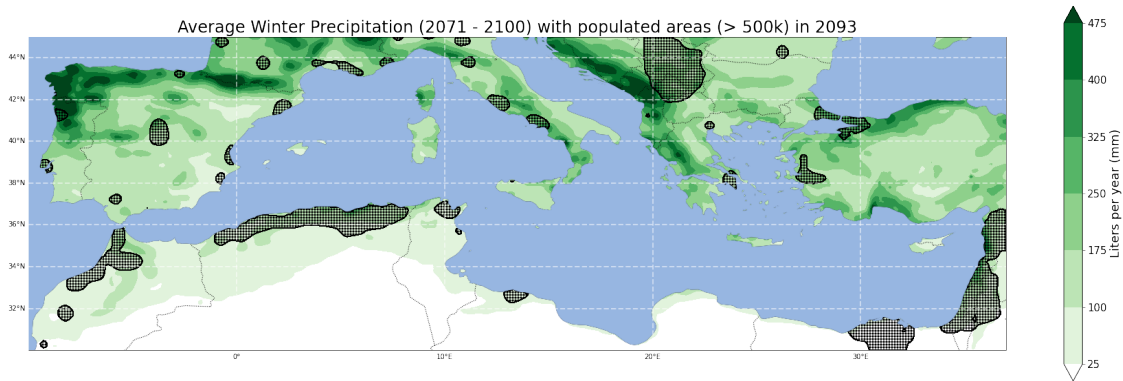
ax.add_feature(cfeature.COASTLINE, linestyle='-')
ax.add_feature(cfeature.BORDERS, linestyle=':');
ax.add_feature(cfeature.OCEAN, zorder=10)

cbar = fig.colorbar(a, ax=ax, fraction = 0.1, label=r'Liters per year (mm')
cbar.ax.tick_params(labelsize=15)
cbar.set_label("Liters per year (mm)", size=18)

gl = ax.gridlines(crs=ccrs.PlateCarree(), draw_labels=True,
    linewidth=2, color='white', alpha=0.5, linestyle='--', ↪
    ↪zorder=11)
gl.top_labels = False # suppress gridline labels on the top
gl.right_labels = False # suppress gridline labels at the right edge

ax.set_title('')
#ax.set_title('Time:{}'.format(nice_time), loc='right');
ax.set_title('Average Winter Precipitation (2071 - 2100) with populated areas ↪
    ↪(> 500k) in 2093', fontsize=24)
plt.savefig("/lhome/cra2022/1.quirino.2_2022/Quirino_Leonardo/Project/
    ↪WinterPrecip7100_Pop_2093_rcp85.png", dpi = 300, ↪
    ↪bbox_inches="tight", pad_inches=0)

```



```
[13]: plt.close()
```

```
[14]: col_map = get_cmap("Greens").copy()
col_map.set_under("white")
precip_levels = np.arange(25,500,75.)

fig = plt.figure(figsize=(30,10))
ax = plt.axes(projection=ccrs.PlateCarree())

#Include a ready-to-use colormap with cmap=<colormap_name>
a = season_JJA_prcp_7100_rcp85.plot.contourf(ax=ax, transform=ccrs.
    ↳PlateCarree(), cmap=col_map, levels = precip_levels, add_colorbar=False)
d = ds_pop.population.plot.contourf(ax=ax, transform=ccrs.
    ↳PlateCarree(), levels=[0,500000], colors='none', hatches=['', '+++'],
    ↳add_colorbar=False)

# Hatch color has to be changed afterwards has edgecolor
d.collections[1].set_edgecolor('Black')

# Add a contour for clarity
ds_pop.population.plot.contour(ax=ax, transform=ccrs.PlateCarree(),
    ↳levels=[500000], colors = 'Black', linewidths=1, add_colorbar=False)

ax.add_feature(cfeature.COASTLINE, linestyle='-')
ax.add_feature(cfeature.BORDERS, linestyle=':');
ax.add_feature(cfeature.OCEAN, zorder=10)

cbar = fig.colorbar(a, ax=ax, fraction = 0.1, label=r'liters per year (mm)')
cbar.ax.tick_params(labelsize=15)
cbar.set_label("Liters per year (mm)", size=18)

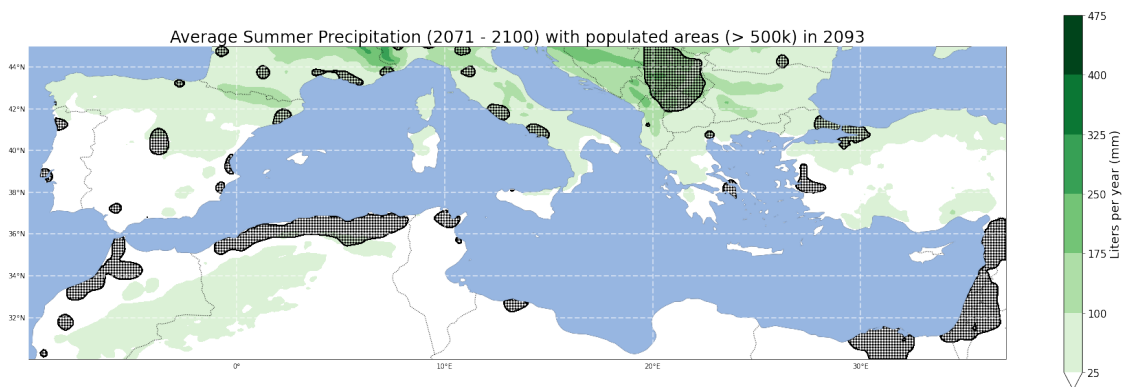
gl = ax.gridlines(crs=ccrs.PlateCarree(), draw_labels=True,
```

```

        linewidth=2, color='white', alpha=0.5, linestyle='--',
        ↪zorder=11)
gl.top_labels = False # suppress gridline labels on the top
gl.right_labels = False # suppress gridline labels at the right edge

ax.set_title('')
#ax.set_title('Time:{}'.format(nice_time), loc='right');
ax.set_title('Average Summer Precipitation (2071 - 2100) with populated areas_
        ↪(> 500k) in 2093', fontsize=24)
plt.savefig("/lhome/cra2022/1.quirino.2_2022/Quirino_Leonardo/Project/
        ↪SummerPrecip7100_Pop_2093_rcp85.png", dpi = 300,
        ↪bbox_inches="tight",pad_inches=0)

```



```
[15]: plt.close()
```

```

[16]: col_map1 = get_cmap("cividis_r").copy()
col_map1.set_under("white")
var_levels = np.arange(100,15000,1000)

fig = plt.figure(figsize=(30,10))
ax = plt.axes(projection=ccrs.PlateCarree())

#Include a ready-to-use colormap with cmap=<colormap_name>
a1 = (season_var_prcp_7100_rcp85).plot.contourf(ax=ax, transform=ccrs.
        ↪PlateCarree(), levels=var_levels, cmap=col_map1, add_colorbar=False)
d = ds_pop.population.plot.contourf(ax=ax, transform=ccrs.
        ↪PlateCarree(), levels=[0,500000], colors='none', hatches=['','+++'],
        ↪add_colorbar=False)

# Hatch color has to be changed afterwards has edgecolor
d.collections[1].set_edgecolor('Black')

# Add a contour for clarity

```



```

ds_pop.population.plot.contour(ax=ax, transform=ccrs.PlateCarree(),
    ↪levels=[500000], colors = 'Black', linewidths=1, add_colorbar=False)

ax.add_feature(cfeature.COASTLINE, linestyle='-')
ax.add_feature(cfeature.BORDERS, linestyle=':');
ax.add_feature(cfeature.OCEAN, zorder=10)

cbar1 = fig.colorbar(a1, ax=ax, fraction = 0.1, label=r'Montly Variance')
cbar1.ax.tick_params(labelsize=15)
cbar1.set_label("Monthly Variance", size=18)

gl = ax.gridlines(crs=ccrs.PlateCarree(), draw_labels=True,
    linewidth=2, color='white', alpha=0.5, linestyle='--',
    ↪zorder=11)

gl.top_labels = False # suppress gridline labels on the top
gl.right_labels = False # suppress gridline labels at the right edge

ax.set_title('')
#ax.set_title('Time:{}'.format(nice_time), loc='right');
ax.set_title('Seasonal Variance of Precipitation (2071 - 2100) with populated_
    ↪areas (> 500k) in 2093', fontsize=24)
plt.savefig("/lhome/cra2022/l.quirino.2_2022/Quirino_Leonardo/Project/
    ↪SeasonalVarPrecip7100_rcp85_Pop_2093.png", dpi = 300,
    ↪bbox_inches="tight",pad_inches=0)

```

