SCEWERO

STRENGTHENING THE RESEARCH CAPACITIES
FOR EXTREME WEATHER EVENTS IN ROMANIA

TRAINING ON AI USE FOR CLIMATE EXTREMES 2026

STATISTICAL DOWNSCALING USING MACHINE LEARNING TECHNIQUES

Hands-on k-Nearest Neighbours to extend seasonal forecast applications to the local scale

Leonardo Aragão

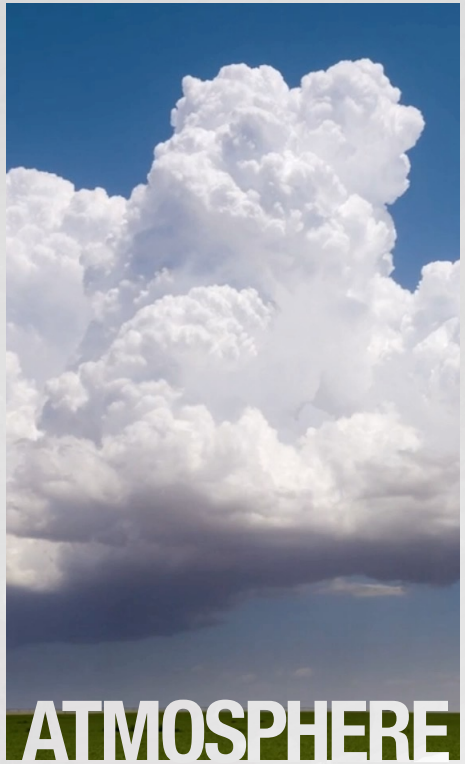
CMCC Foundation - Euro-Mediterranean Center on Climate Change
Earth SYstem modeling and Data Assimilation (ESYDA)

Funded by the European Union
Grant Agreement 101159497

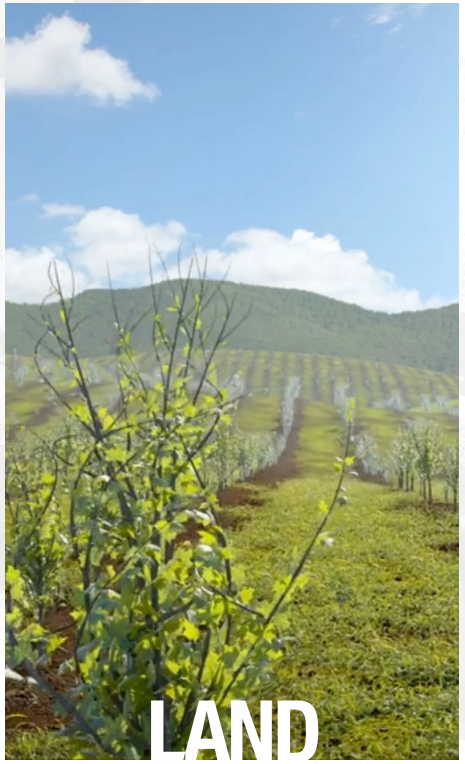
EARTH SYSTEM MODELS

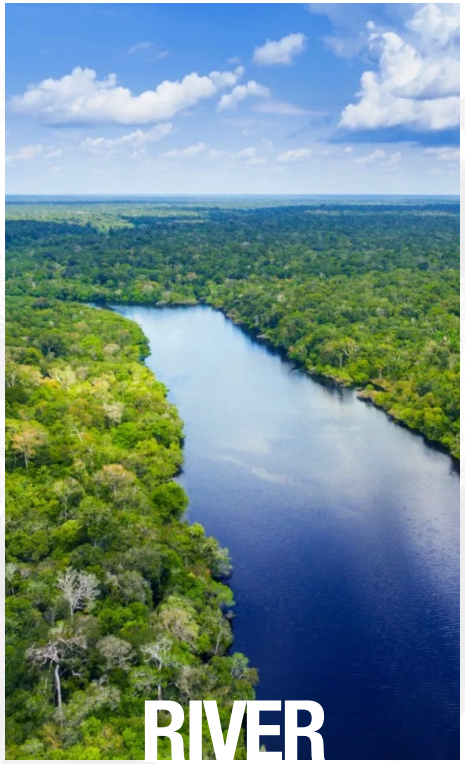
CMCC Seasonal Prediction System v4

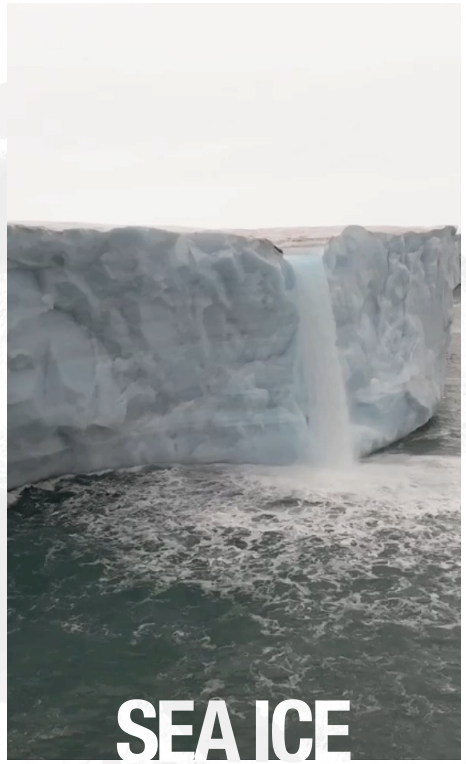
SCEWERO











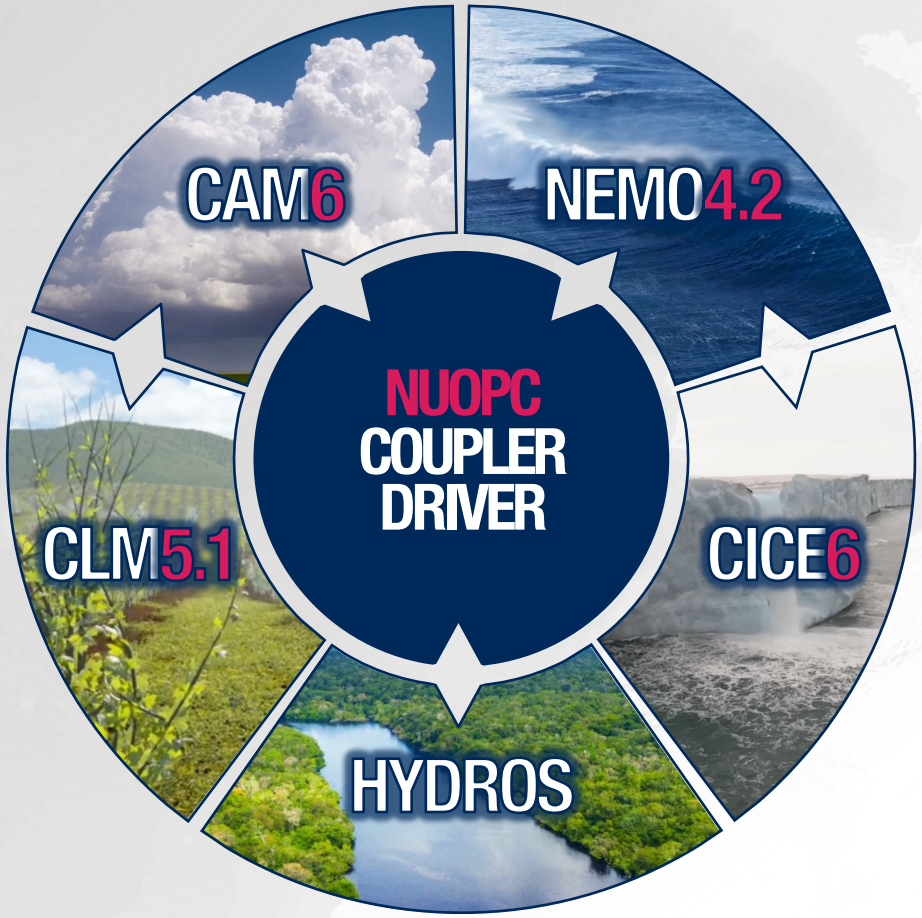
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EARTH SYSTEM MODELS

CMCC Seasonal Prediction System v4 (v3.5)

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INITIALISATIONS & ENSEMBLE

Copernicus Climate Change Services (C3s) framework

Perturbed Initial Conditions

10 Atmosphere x **3** Land x **9** Ocean = **270** Possibilities

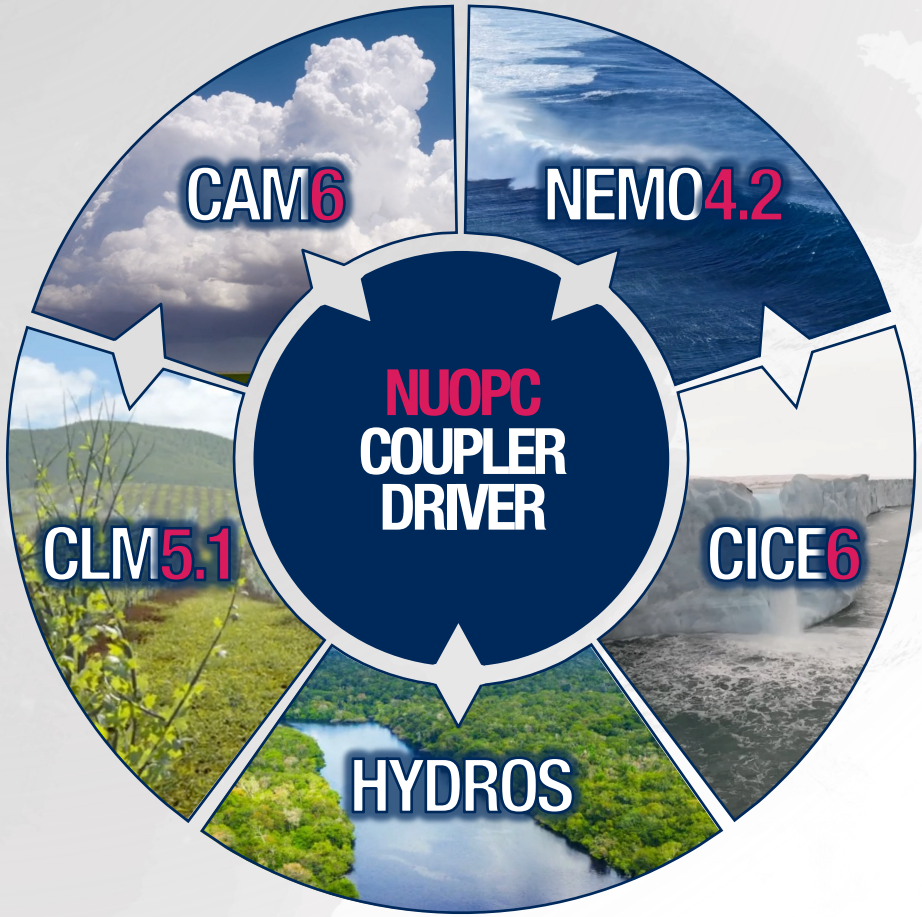
More information in: Sanna *et al.* (2025) // DOI 10.25424/cmcc-dkcv-fs25

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EARTH SYSTEM MODELS

CMCC Seasonal Prediction System v4 (v3.5)

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INITIALISATIONS & ENSEMBLE

Copernicus Climate Change Services (C3s) framework

270 Possibilities

Random Selection

50 Ensemble Members*

*Hindcast mode (30 in forecast mode).

More information in: Sanna *et al.* (2025) // DOI 10.25424/cmcc-dkcv-fs25

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EARTH SYSTEM MODELS

CMCC Seasonal Prediction System v4 (v3.5)

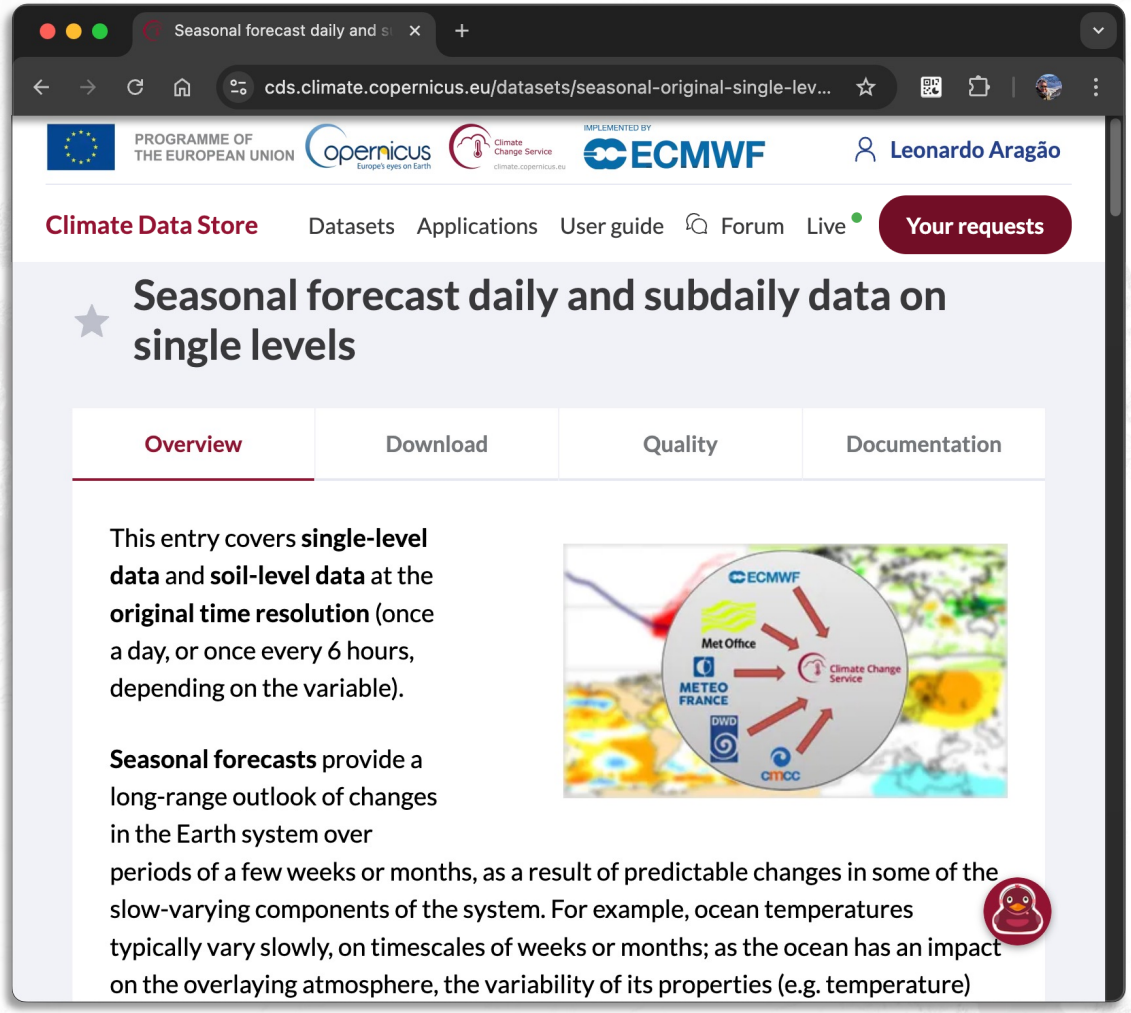
INITIALISATIONS & ENSEMBLE

Copernicus Climate Change Services (C3s) framework

270
Possibilities

Random Selection

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EARTH SYSTEM MODELS

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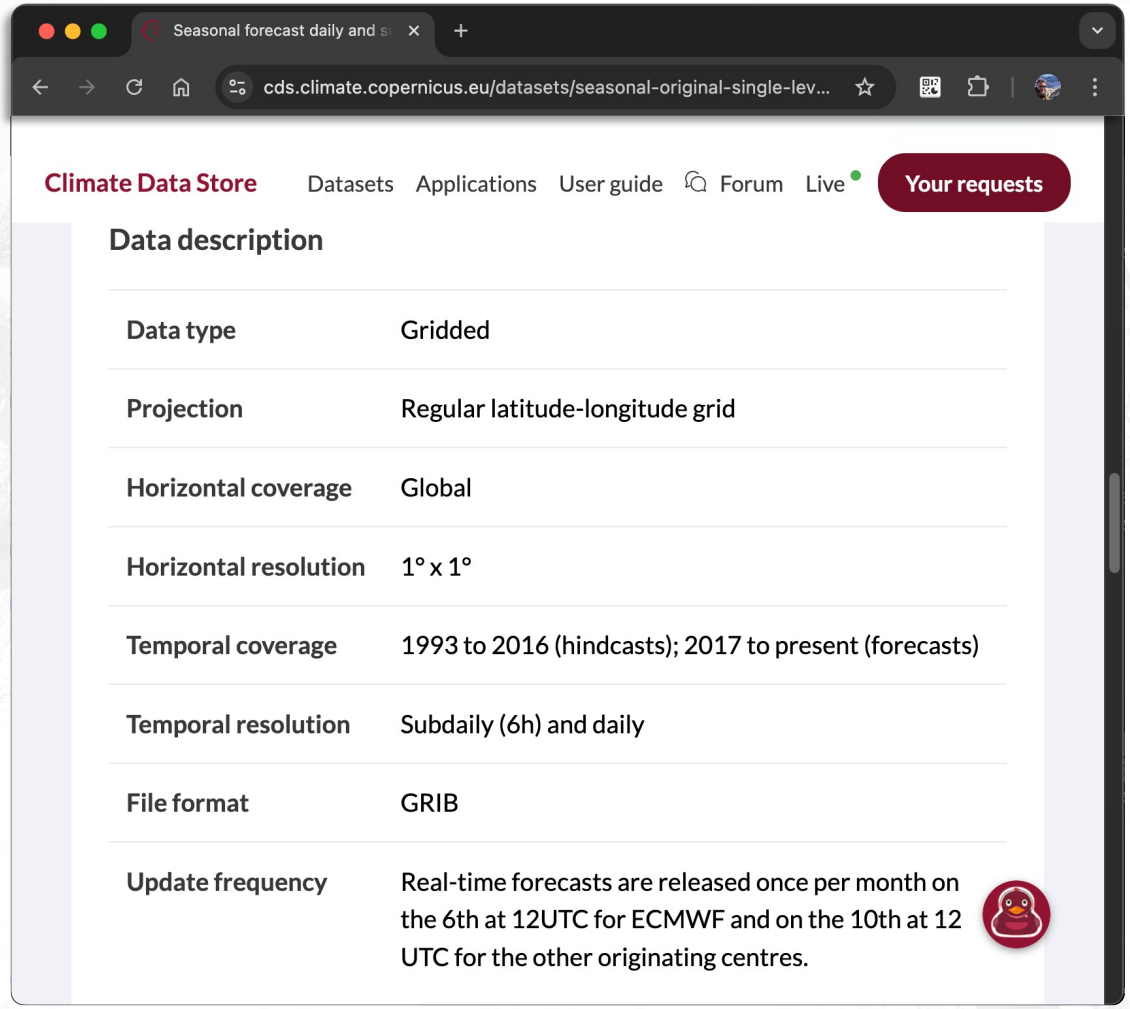
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EARTH SYSTEM MODELS

CMCC Seasonal Prediction System v4 (v3.5)

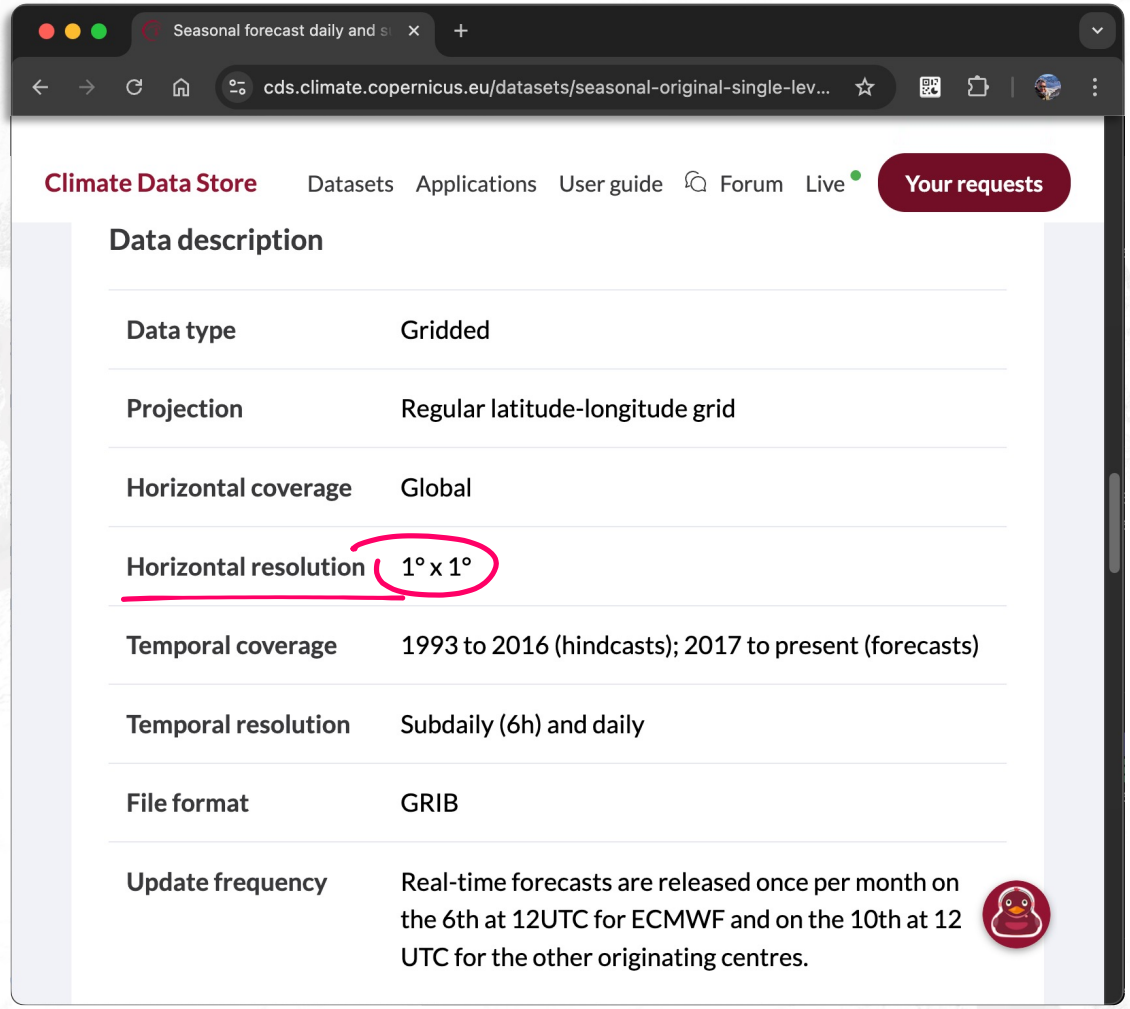
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Copernicus Climate Change Services (C3s) framework

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STATISTICAL DOWNSCALING

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OUR SCOPE

"The general objective is to develop a computational algorithm in Python language that allows downscaling low-resolution meteorological data (historical or forecast) using machine learning techniques."

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SCEWERO

OUR SCOPE

The general objective is to develop a computational algorithm in Python language that allows downscaling low-resolution meteorological data (historical or forecast) using machine learning techniques.

EXPERIMENT

"To evaluate the k-Nearest Neighbours (kNN) machine-learning method for downscaling daily 2m temperature fields over Romania using a 10-year Reanalysis of ERA5 and 6-month predictions from 50 members of CMCC Seasonal Prediction System v4.0 (SPS)."

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DATA & METHODS

SPS4 statistical downscaling over Romania (2016-2025)

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SPS Initial Conditions
REG Global
DOM 180×360
RES 1.00° Daily
PER 01-06/2026

ERA5 Ground Truth
REG Global
DOM 720×1440
RES 0.25° Hourly
PER 1940-Now

T2M	Daily average 2m Temperature
T2MN	Daily minimum 2m Temperature
T2MX	Daily maximum 2m Temperature
D2M	Daily average 2m Dew-point Temperature
SSHF	Daily average Surface Sensible Heat Flux
SLHF	Daily average Surface Latent Heat Flux



TP	Daily accumulated Total Precipitation
MSL	Daily average Mean Sea Level Pressure
U10	Daily average zonal wind component
V10	Daily average meridional wind component
U	Daily average zonal wind component at 500 hPa
V	Daily average meridional wind component at 500 hPa
Z	Daily average Geopotential Height at 500 hPa

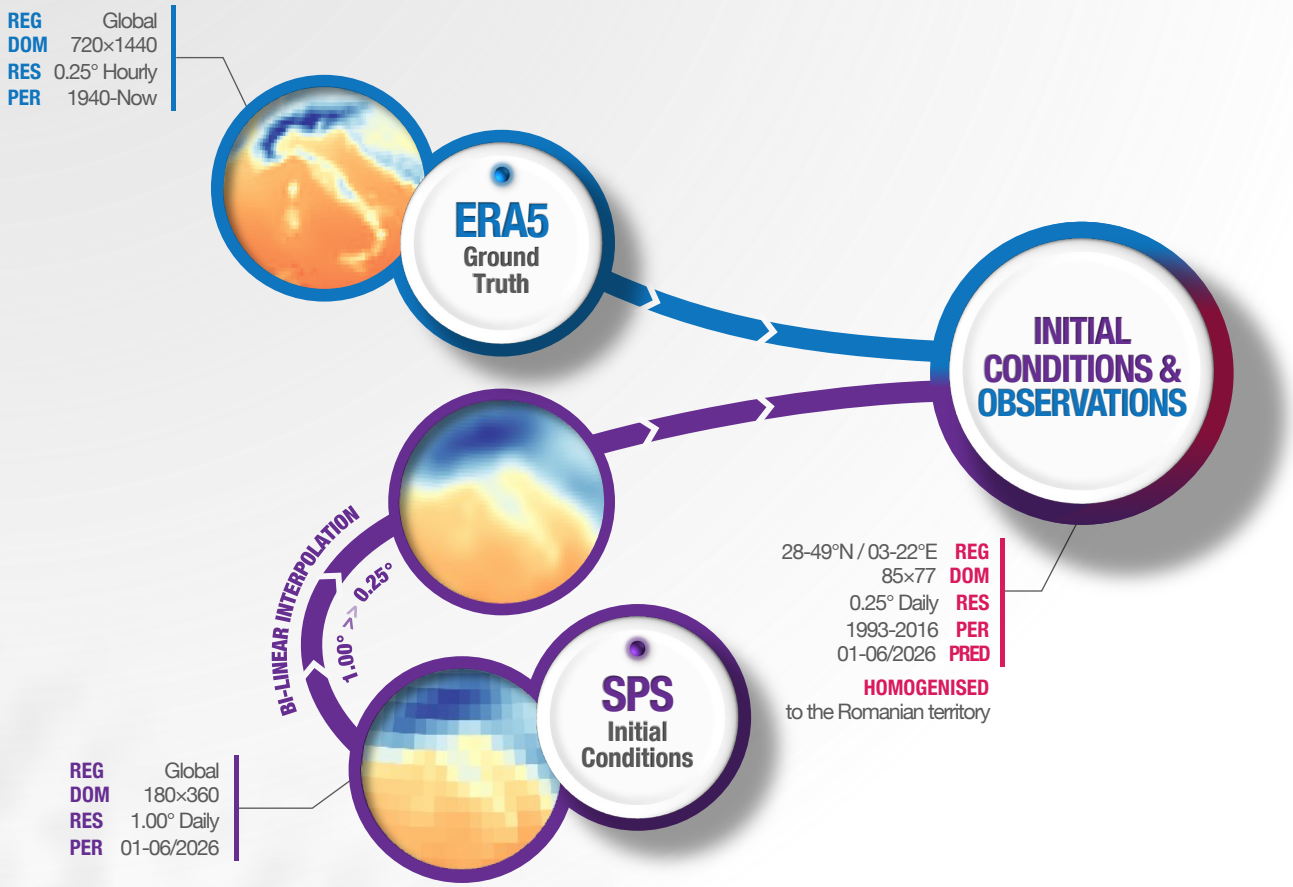
*k*NN
T2M T2MN T2MX

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DATA & METHODS

SPS4 statistical downscaling over Romania (2016-2025)

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T2M	Daily average 2m Temperature
T2MN	Daily minimum 2m Temperature
T2MX	Daily maximum 2m Temperature
D2M	Daily average 2m Dew-point Temperature
SSHF	Daily average Surface Sensible Heat Flux
SLHF	Daily average Surface Latent Heat Flux
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DATA & METHODS

SPS4 statistical downscaling over Romania (2016-2025)

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REG Global
DOM 720×1440
RES 0.25° Hourly
PER 1940-Now

ERA5
Ground Truth

BI-LINEAR INTERPOLATION
1.00° >> 0.25°

SPS
Initial Conditions

REG Global
DOM 180×360
RES 1.00° Daily
PER 01-06/2026

INITIAL CONDITIONS & OBSERVATIONS

28-49°N / 03-22°E REG
85×77 DOM
0.25° Daily RES
1993-2016 PER
01-06/2026 PRED

HOMOGENISED
to the Romanian territory

DIMENSIONS
150×11
$(w.p) \times n$

n = 11 Predictors
p = 10 years (2016-2025)
w = 14+1 Days Window

FEATURE VECTOR

WEATHER GENERATOR VARIABLES >>>
+T2MN
+T2MX

Euclidean Distance

k Analog Days

Proportional to Observational Time-series Length
$k = \sqrt{(w+1)p - 1} \approx 13$

BISQUARE WEIGHT FUNCTION

kNN
T2M T2MN T2MX

EACH PREDICTED DAY FROM THE START-DATE

T2MN T2MX

T2M	D2M	SSHF	SLHF	TP	MSL	U10	V10	U	V	Z	D_{-7} Y_1
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
T2M	D2M	SSHF	SLHF	TP	MSL	U10	V10	U	V	Z	D_{+7} Y_{10}

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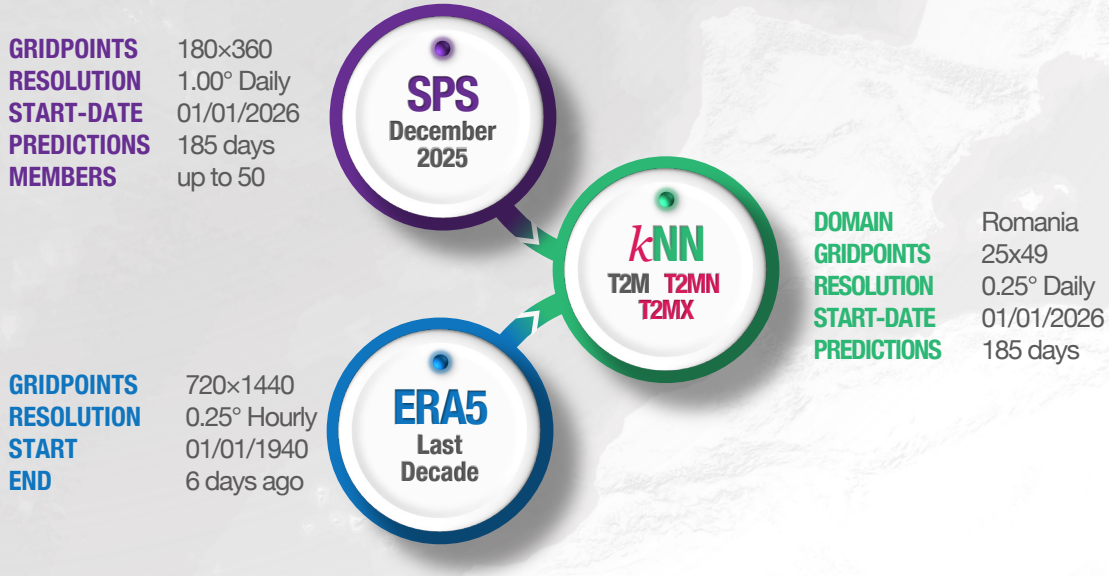
SCEWERO EXPERIMENT

SCEWERO EXPERIMENT

Training on AI use for climate extremes

SCEWERO

*Use the k-Nearest Neighbours method to downscale daily 2m temperature fields (**T2M**, **T2MN**, and **T2MX**) over Romania produced by the SPS4 seasonal prediction issued at the end of December 2025. Base this process on ERA5 Reanalysis data from the previous decade and incorporate a set of predictors of your choice without considering **T2MN** and **T2MX**.*



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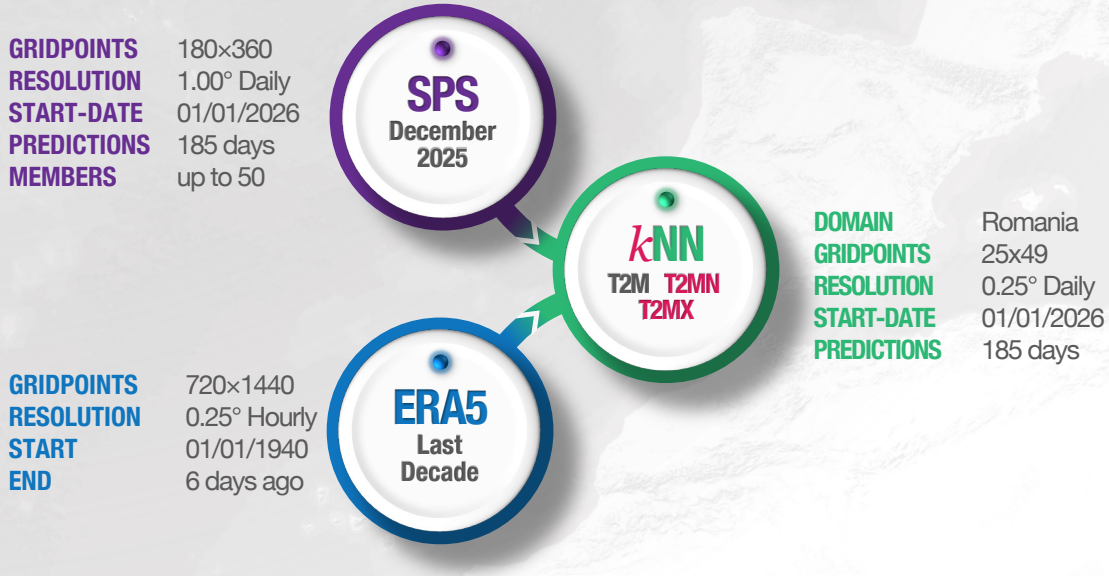
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SCEWERO EXPERIMENT

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*Use the k-Nearest Neighbours method to downscale daily 2m temperature fields (**T2M**, **T2MN**, and **T2MX**) over Romania produced by the SPS4 seasonal prediction issued at the end of December 2025. Base this process on ERA5 Reanalysis data from the previous decade and incorporate a set of predictors of your choice without considering **T2MN** and **T2MX**.*



You have 100 coins to assemble your team of predictors!

Which ones would you choose?



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KNN PROCESSING

kNN PROCESSING

Roadmap to downscale seasonal predictions

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kNN PROCESSING

Roadmap to downscale seasonal predictions

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So_EnvironmentCheck.sh

```
#!/usr/bin/env bash

# 1. Check if Python 3 is installed
# 2. Check/install NCO package
# 3. Install missing Python libraries
# 4. Create verification scripts
# 5. Run verification tests
# ============================================================

set -e

echo "========================================="
echo " Checking Python installation"
echo "========================================="

# ------------------------------------------------------------
# Check Python 3
# ------------------------------------------------------------
if ! command -v python3 &> /dev/null; then
echo "Python3 not found."
```

Step 0 1 2 3 4 5 6 7 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

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echo " Checking Python installation"
echo "========================================="

# ------------------------------------------------------------
# Check Python 3
# ------------------------------------------------------------
if ! command -v python3 &> /dev/null; then
echo "Python3 not found."
```

→ Scripts Language

→ netCDF decoder

→ Scripts needs

So_EnvironmentCheck.sh

Step 0 1 2 3 4 5 6 7 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

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Line 120 ▸

```
# ------------------------------------------------------------
# Python libraries installable via pip
# ------------------------------------------------------------
PIP_LIBS=(
          cartopy
          netCDF4
          numpy
          matplotlib
          pandas
          scipy
          xarray
         )

for lib in "${PIP_LIBS[@]}"; do

    echo
    echo "Checking ${lib}..."

    if python3 -c "import ${lib}" &> /dev/null; then
        echo "${lib} already installed."
```

So_EnvironmentCheck.sh

Step 0 1 2 3 4 5 6 7 8

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S0_EnvironmentCheck.sh

0

S1_GetERA5.py

```python
#!/usr/bin/env python

import os
import cdsapi

# Period
Years = [2016,2025]

# Output directory (check if the user has access to write)
OutDIR = os.getcwd()+'/ERA5/'

# Filename standard
OutTAG = 'RawERA5_SCEWERO'

# Domain Boundaries in decimal degrees [N,W,S,E]
Domain = [] # Global
Domain = [ 47.00, 09.00, 43.00, 14.00 ] # BO Domain
Domain = [ 70.00,-45.00, 15.00, 70.00 ] # MedCordex
Domain = [ 50.00, 02.00, 27.00, 23.00 ] # IRIDE Domain
Domain = [ 49.00, 19.00, 43.00, 31.00 ] # SCEWERO Romania
```

Step 1 2 3 4 5 6 7 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh

0

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import os
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# Output directory (check if the user has access to write)
OutDIR = os.getcwd()+'/ERA5/'

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OutTAG = 'RawERA5_SCEWERO'
```

→ not included in Step0

→ Replace all " / " with " \ " if your system is Windows

_2016_t2m.nc

```python
# Domain Boundaries in decimal degrees [N,W,S,E]
Domain = [] # Global
Domain = [ 47.00, 09.00, 43.00, 14.00 ] # BO Domain
Domain = [ 70.00,-45.00, 15.00, 70.00 ] # MedCordex
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S1_GetERA5.py

Step 1 2 3 4 5 6 7 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

Line 76 ▸

S0_EnvironmentCheck.sh

0

S1_GetERA5.py

Step 1 2 3 4 5 6 7 8

```
#|| SINGLE-LEVELS ├──────────────────────────────────────────
Level = f'reanalysis-era5-single-levels'

Variables = [['t2m' ,'2m_temperature'              ],
             ['d2m' ,'2m_dewpoint_temperature'     ],
             ['tp' ,'total_precipitation'          ],
             ['u10' ,'10m_u_component_of_wind'     ],
             ['v10' ,'10m_v_component_of_wind'     ],
             ['msl' ,'mean_sea_level_pressure'     ],
             ['slhf','surface_latent_heat_flux'    ],
             ['sshf','surface_sensible_heat_flux'  ]
            ]

for var in Variables:
    OutFILE = os.path.join(OutDIR,f'{OutTAG}_{Year}_{var[0]}.nc')
    Request.update({'variable' : [var[1]]})

    if not os.path.exists(OutFILE):
        c.retrieve(Level,Request,OutFILE)
        print(f'\n\n>>> {OutTAG}_{Year}_{var[0]}.nc [ C O M P L E T E ]')
```

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kNN PROCESSING

Roadmap to downscale seasonal predictions

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Line 101 ▸

S0_EnvironmentCheck.sh

```
#|| PRESSURE-LEVELS (500hPa) ├──────────────────────────────────
Level = f'reanalysis-era5-pressure-levels'
Request.update({'pressure_level' : ['500']})

Variables = [['z' ,'geopotential'         ],
             ['u' ,'u_component_of_wind' ],
             ['v' ,'v_component_of_wind' ]
             ]

for var in Variables:
    OutFILE = os.path.join(OutDIR,f'{OutTAG}_{Year}_{var[0]}.nc')
    Request.update({'variable' : [var[1]]})

    if not os.path.exists(OutFILE):
        c.retrieve(Level,Request,OutFILE)
        print(f'\n\n>>> {OutTAG}_{Year}_{var[0]}.nc [ C O M P L E T E ]')
        print(f' {var[1]}\n\n')

#┌──────────────────────────────────────────────────────────────
#|| S U B M I S S I O N
```

Use a single level to have your request accepted

S1_GetERA5.py

0

Step 1 2 3 4 5 6 7 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh

S1_GetERA5.py

```python
#!/usr/bin/env python

import os
import numpy as np
import netCDF4 as nc
from datetime import datetime as dt

#┌──────────────────────────────────────────────────────────────┐
#│ U S E R - S E T T I N G                                      │
#└──────────────────────────────────────────────────────────────┘

# Working directory (check if the user has access to write)
OutDIR = os.getcwd()+'/ERA5/'

# Filename standard
OutTAG = 'ERA5_SCEWERO'

# Domain Boundaries in decimal degrees [N,W,S,E]
Domain = [ 49.00, 19.00, 43.00, 31.00 ] # SCEWERO Romania
```

S2_ERA5toSCEWERO.py

0 1 Step 2 3 4 5 6 7 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

Line 105 ▸

S0_EnvironmentCheck.sh

S1_GetERA5.py

```
Temp = (f'{len(Time)} hours (‘+
        f'{Date[0][2]:0>2}/{Date[0][1]:0>2}/{Date[0][0]} {Date[-1][3]:0>
        f'{Date[-1][2]:0>2}/{Date[-1][1]:0>2}/{Date[-1][0]} {Date[-1][3]
print(f'| {f"Initial period ":···<29} {Temp:<60} |')
print(f'| {"Initial variable shape ":···<29} {str(Var.shape):<60} |')
Temp = f'{"".join([f"{f(Var):>12.4f}" for f in [np.nanmin,np.nanmean,np.
print(f'| {"Initial variable range ":···<29} {Temp:<60} |')


# Reducing from Hourly to Daily
Time = Time[iDays[:,0]]
if VarSET[var]=='t2mn': #================== Apply daily minima
    Var = np.array([np.nanmin( Var[day],axis=0) for day in iDays])
elif VarSET[var]=='t2mx': #================== Apply daily maxima
    Var = np.array([np.nanmax (Var[day],axis=0) for day in iDays])
elif VarSET[var]=='tp': #============ Apply daily accumulation
    Var = np.array([np.nansum (Var[day],axis=0) for day in iDays])
else: #==================================== Apply daily average
    Var = np.array([np.nanmean(Var[day],axis=0) for day in iDays])
```

Use this lot to configure the method applied to each variable

S2_ERA5toSCEWERO.py

Step 0 1 2 3 4 5 6 7 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh

S1_GetERA5.py

Line 105 ▸

```
# Units homogenising
iVar = str(VarSET[var])
if iVar in ['d2m','t2m','t2mn','t2mx']: #=========== [k] >> [°C]
    Var = Var-273.15
if iVar in ['sshf','slhf']: #================ [J/m².h] >> [W/m²]
    Var = Var/3600
if iVar in ['tp']: #================================ [m] >> [mm]
    Var = Var*1000
if iVar in ['msl']: #============================== [Pa] >> [hPa]
    Var = Var/100
if iVar in ['z']: #============================== [m²/s²] >> [m]
    Var = Var/9.80665

Temp = (f'{len(Time)} days ('+
f'{Date[0][2]:0>2}/{Date[0][1]:0>2}/{Date[0][0]} to '+
f'{Date[-1][2]:0>2}/{Date[-1][1]:0>2}/{Date[-1][0]})')
print(f'| {f"Final period ":···<29} {Temp:<60} |')
print(f'| {"Final variable shape ":···<29} {str(Var.shape):<60} |')
Temp = f'{"".join([f"{f(Var):>12.4f}" for f in [np.nanmin,np.nanmean,np.
print(f'| {"Final variable range ":···<29} {Temp:<60} |')
```

S2_ERA5toSCEWERO.py

Step 0 1 2 3 4 5 6 7 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh

S1_GetERA5.py

S2_ERA5toSCEWERO.py

```
#!/bin/sh
#┌──────────────────────────────────────────────────────────────
#|| CMCC Foundation Euro-Mediterranean Center on Climate Change
#|| RETRIEVING SPS4 FROM JUNO (CMCC HPC) FOR SCEWERO
#|| by leonardo.aragao@cmcc.it
#└──────────────────────────────────────────────────────────────
# v.Beta

Forecast="202601"
iVAR=("surface_tas" "surface_tdps" "surface_lwepr" "surface_uas" "surface
oVAR=("t2m" "d2m" "tp" "u10" "v10" "u" "v" "msl" "z" "slhf" "sshf")
iDIR="/data/products/CMCC_SPS4/C3S_daily/${Forecast}/cmcc_CMCC-CM3-v20231
oDIR="/work/cmcc/la34023/SCEWERO/SPS4/"

cd $oDIR

nVAR=${#iVAR[@]}
for ((i=0; i<nVAR; i++)); do
    for member in $(printf "%02d\n" $(seq 1 50)); do
        file="RawSPS4_SCEWERO_${Forecast}_${member}_${oVAR[i]}.nc"
```

You can also adapt Step1 to retrieve SPS4 from CS3

S3_GetSPS4.sh

0 1 2 Step 3 4 5 6 7 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh

S1_GetERA5.py

S2_ERA5toSCEWERO.py

S3_GetSPS4.sh

```
#!/usr/bin/env python

import os
import warnings
import numpy as np
import netCDF4 as nc
from datetime import datetime as dt
from scipy.interpolate import RegularGridInterpolator

#┌──────────────────────────────────────────────────────────────────────────┐
#│ U S E R - S E T T I N G                                                  │
#└──────────────────────────────────────────────────────────────────────────┘

# Working directory (check if the user has access to write)
WorkDIR = os.getcwd()+'/SPS4/'

# Domain Boundaries in decimal degrees [N,W,S,E]
Domain = [ 49.00, 19.00, 43.00, 31.00 ] # SCEWERO Romania

#┌──────────────────────────────────────────────────────────────────────────┐
```

Main difference to Step2

S4_SP4toSCEWERO.py

0 1 2 3 Step 4 5 6 7 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

Line 53 ▸

S0_EnvironmentCheck.sh **0**

S1_GetERA5.py **1**

S2_ERA5toSCEWERO.py **2**

S3_GetSPS4.sh **3**

```
#┌──────────────────────────────────────────────────────────────────────────┐
#│ D A T A   P R O C E S S I N G                                            │
#└──────────────────────────────────────────────────────────────────────────┘

def ProcessFILE(filename:str):

# Files selection
print(f'\n┌{"─"*98}┐\n│ {f"Processing file ":···<29} {filename:<60} │')
iVar = [['t2m','tas'],['d2m','tdps'],['msl','psl'],['z','zg'],['tp','lwep
        ['u','ua'],['u10','uas'],['v','va'],['v10','vas'],
        ['sshf','hfss'],['slhf','hfls']]
iVar,eVar = iVar[np.where(np.array(iVar)==filename.split('_')[-1][:-3])[0
Temp = f'{iVar} ({eVar})'
print(f'│ {f"Variable ":···<29} {Temp:<60} │')

# Importing data
InputDATA = nc.Dataset(WorkDIR+filename)

Lat = np.flip(InputDATA.variables['lat'][:],0)
Lon = InputDATA.variables['lon'][:]
```

Homogenise variable names

S4_SP4toSCEWERO.py **4**

Step **5 6 7 8**

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh 0

S1_GetERA5.py 1

S2_ERA5toSCEWERO.py 2

S3_GetSPS4.sh 3

S4_SP4toSCEWERO.py 4

```
#!/usr/bin/env python
print('\n\n\n')
iP = [
  '┌──────────────────────────────────────────────────────────────────────────┐
  '│ CMCC Foundation Euro-Mediterranean Center on Climate Change
  '│ STATISTICAL DOWNSCALING FOR CMCC SEASONAL PREDICTION SYSTEM v4
  '│ from 1-degree to 0.25-degree using the k-Nearest Neighbour Method
  '└──────────────────────────────────────────────────────────────────────────┘
  '  by leonardo.aragao@cmcc.it
[print(i) for i in iP]; sP=len(iP)

import os
import sys
import time
import numpy as np
import netCDF4 as nc
from datetime import datetime as dt
from scipy.interpolate import RegularGridInterpolator

StartPOINT = dt.now()
```

S5_kNNtoSCEWERO.py Step 5

6 7 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh
S1_GetERA5.py
S2_ERA5toSCEWERO.py
S3_GetSPS4.sh
S4_SP4toSCEWERO.py
S5_kNNtoSCEWERO.py

Step 0 1 2 3 4 5 6 7 8

Line 54 ▸

```
        f'||{"_"*74}|_|_|_|_|_|_|_|_|_|_|_|\n\n\n'] #P
    [print(i) for i in Temp] #P
    sys.exit()

# Working directories
DirBASE = os.getcwd()+'/'
DirERA5 = DirBASE+'ERA5/' # Ground truth data directory
DirSPS4 = DirBASE+'SPS4/' # Initial conditions data directory
DirkNN = DirBASE+'kNN/' # Downscaled output data directory

# Domain Boundaries in decimal degrees [N,W,S,E]
Domain = [ 49.00, 19.00, 43.00, 31.00 ] # SCEWERO Romania

# I/O Variables
iVar = UserVAR
oVar = ['t2m','t2mn','t2mx']

# kNN centred time window (in days)
tWIN = 15
```

Set your predictands!

kNN time window control

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh 0

S1_GetERA5.py 1

S2_ERA5toSCEWERO.py 2

S3_GetSPS4.sh 3

S4_SP4toSCEWERO.py 4

Line 296 ▸

```
vLat.standard_name    = 'latitude'
vLat.long_name        = 'latitude'
vLat.units            = 'degrees_north'
vLat.stored_direction = 'decreasing'
vLat[:]               = Lat

vLon = ncFILE.createVariable('longitude','f4',('longitude',))
vLon.standard_name    = 'longitude'
vLon.long_name        = 'longitude'
vLon.units            = 'degrees_east'
vLon[:]               = Lon

if VarNAME=='t2m':
   vVar = ncFILE.createVariable(VarNAME,'f4',('valid_time','latitude','lo
   vVar.short_name    = VarNAME
   vVar.standard_name = '2m_temperature'
   vVar.long_name     = '2 metre temperature'
   vVar.units         = 'celsius degree'
   vVar.method        = 'daily average'
   vVar[:,:,:]        = Var
```

If you change the predictands, modify also the netcdf export lot

S5_kNNtoSCEWERO.py Step 5

6 7 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh
S1_GetERA5.py
S2_ERA5toSCEWERO.py
S3_GetSPS4.sh
S4_SP4toSCEWERO.py
S5_kNNtoSCEWERO.py

0 1 2 3 4 5

```
#!/bin/sh

#┌──────────────────────────────────────────────────────────────
#|| CMCC Foundation Euro-Mediterranean Center on Climate Change
#|| RUN S5_kNNtoSCEWERO.py FOR 50 SPS4 MEMBERS
#|| by leonardo.aragao@cmcc.it
#└──────────────────────────────────────────────────────────────
# v.Beta

for member in $(seq 1 50); do
    python S5_kNNtoSCEWERO.py -m $member -v t2m tp d2m sshf u10 msl u z
done
```

Set your predictors up to 100 coins

Add an ampersand (&) at the end to run in parallel (large **RAM** memory-consuming)

S6_RunkNN_Members.sh

Step 6 7 8

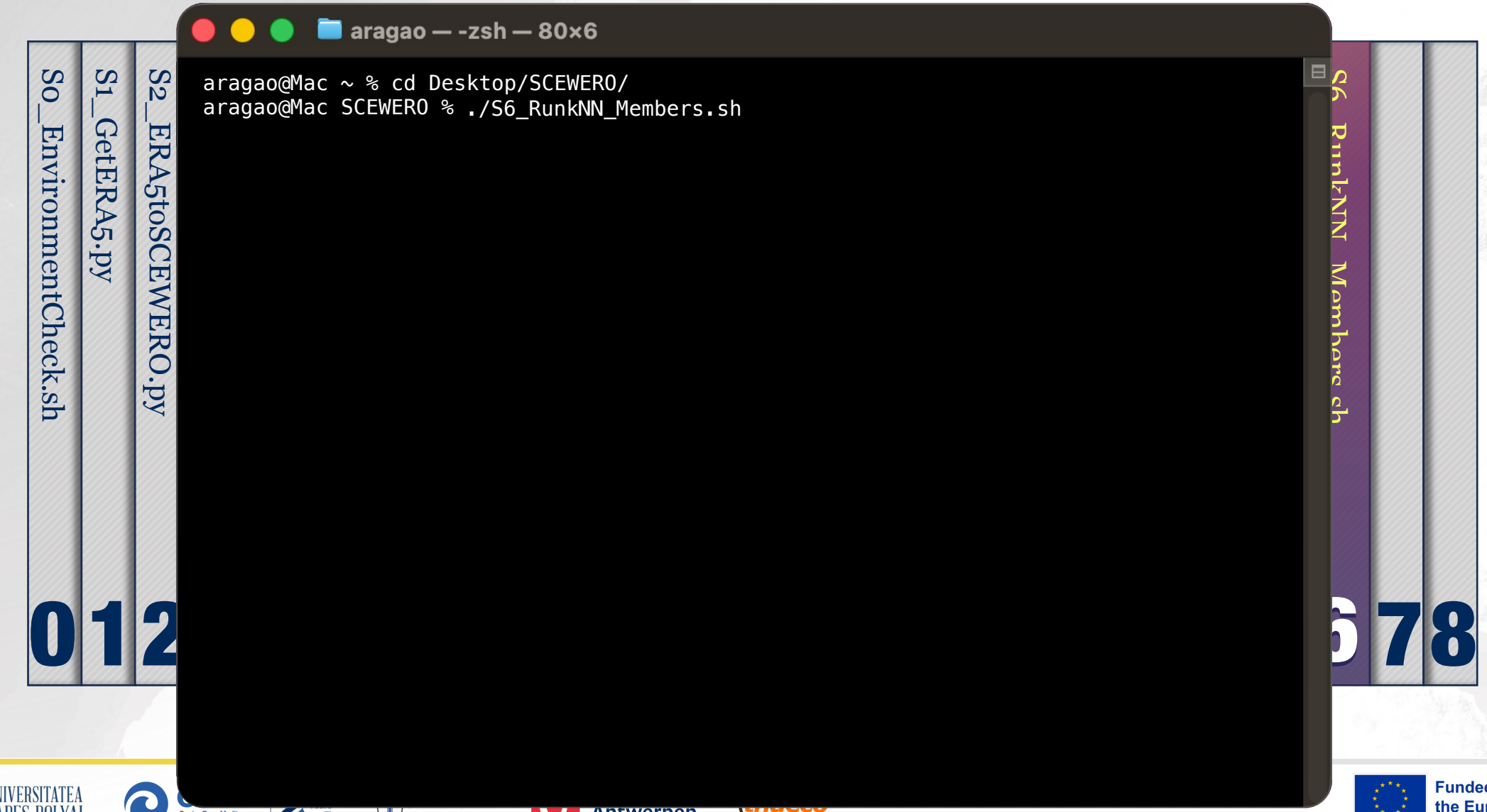
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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO



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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

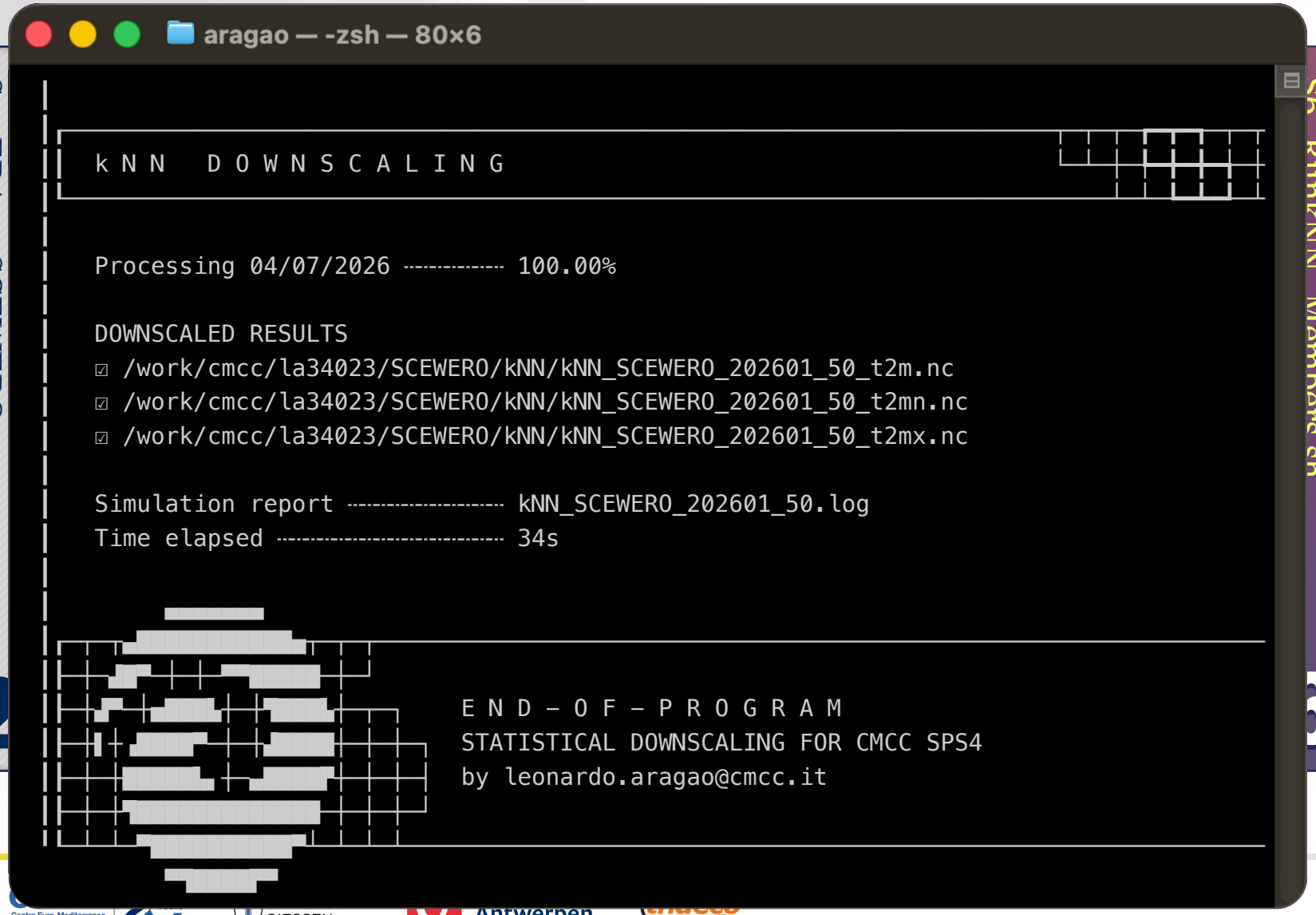
S0_EnvironmentCheck.sh

S1_GetERA5.py

S2_ERA5toSCEWERO.py

S6_RunkNN_Members.sh

0 1 2 6 7 8



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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh
S1_GetERA5.py
S2_ERA5toSCEWERO.py
S3_GetSPS4.sh
S4_SP4toSCEWERO.py
S5_kNNtoSCEWERO.py
S6_RunkNN_Members.sh
S7_EnsembleMeans.py

0 1 2 3 4 5 6 Step 7 8

```
#!/usr/bin/env python
import os
import time
import numpy as np
import netCDF4 as nc

# Define the number of members to consider
TotMEM = 50

# Working directories
DirBASE = os.getcwd()+'/'
DirSPS4 = DirBASE+'SPS4/' # Initial conditions data directory
DirkNN = DirBASE+'kNN/' # Downscaled output data directory

# Domain Boundaries in decimal degrees [N,W,S,E]
Domain = [ 49.00, 19.00, 43.00, 31.00 ] # SCEWERO Romania

# I/O Variables
oVar = ['t2m','t2mn','t2mx']
```

Adjust if needed

Adjust if needed

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh 0

S1_GetERA5.py 1

S2_ERA5toSCEWERO.py 2

aragao — -zsh — 80×6

```
aragao@Mac ~ % cd Desktop/SCEWERO/
aragao@Mac SCEWERO % python S7_EnsembleMeans.py

☑ kNN_SCEWERO_202601_00_t2m.nc
☑ kNN_SCEWERO_202601_00_t2mn.nc
☑ kNN_SCEWERO_202601_00_t2mx.nc
☑ SPS4_SCEWERO_202601_00_t2m.nc

aragao@Mac SCEWERO %
```

S7_EnsembleMeans.py ep 7 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh 0

S1_GetERA5.py 1

S2_ERA5toSCEWERO.py 2

aragao — -zsh — 80×6

```
aragao@Mac ~ % cd Desktop/SCEWERO/
aragao@Mac SCEWERO % python S7_EnsembleMeans.py

☑ kNN_SCEWERO_202601_00_t2m.nc
☑ kNN_SCEWERO_202601_00_t2mn.nc
☑ kNN_SCEWERO_202601_00_t2mx.nc
☑ SPS4_SCEWERO_202601_00_t2m.nc

aragao@Mac SCEWERO % cd kNN/
aragao@Mac kNN % ncdump -h kNN_SCEWERO_202601_00_t2m.nc
```

S7_EnsembleMeans.py 7

8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh

S1_GetERA5.py

S2_ERA5toSCEWERO.py

S7_EnsembleMeans.py

0 1 2 ep 7 8

aragao — -zsh — 80×6

```
aragao@Mac kNN % ncdump -h kNN_SCEWERO_202601_00_t2m.nc
netcdf kNN_SCEWERO_202601_00_t2m {
dimensions:
        valid_time = 185 ;
        latitude = 25 ;
        longitude = 49 ;
variables:
        double valid_time(valid_time) ;
                valid_time:standard_name = "time" ;
                valid_time:units = "seconds since 1970-01-01" ;
                valid_time:calendar = "proleptic_gregorian" ;
        float latitude(latitude) ;
                latitude:standard_name = "latitude" ;
                latitude:long_name = "latitude" ;
                latitude:units = "degrees_north" ;
                latitude:stored_direction = "decreasing" ;
        float longitude(longitude) ;
                longitude:standard_name = "longitude" ;
                longitude:long_name = "longitude" ;
                longitude:units = "degrees_east" ;
        float t2m(valid_time, latitude, longitude) ;
                t2m:_FillValue = NaNf ;
                t2m:short_name = "t2m" ;
                t2m:standard_name = "2m_temperature" ;
                t2m:long_name = "2 metre temperature" ;
                t2m:units = "celsius degree" ;
                t2m:method = "daily average" ;
```

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Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh 0

S1_GetERA5.py 1

S2_ERA5toSCEWERO.py 2

S3_GetSPS4.sh 3

S4_SP4toSCEWERO.py 4

S5_kNNtoSCEWERO.py 5

S6_RunkNN_Members.sh 6

S7_EnsembleMeans.py 7

```
# Generated using ChatGPT Free using the following prompt:
"""
Write a Python script that produces the results of statistical downscalin
1. The first results section will present maps centred on Romania, with f
1a-f. Monthly averages (lead months 1-6), in this case: (a) January to (f
1g-j. Quarterly average (lead season 1-4), in this case: (g) JFM, (h) FMA
Use a uniform temperature scale across all figures (1a-j) for a fair comp
2. The second section follows the same formats and periods as section 1,
3. Follows the section 1 format, but with only one map evaluating the sta
4. Follows the section 1 format, but with only one map evaluating the RMS
5. Follows the section 1 format, but with only one map evaluating the cor
6. Create a figure with 4 graphs side by side, each one with the aspect r
6. Reproduce the same results from section 5, but present monthly average
The source files can be found in the following directories and filename f
SPS4
< f'{os.getcwd()}SPS4/SPS4_SCEWERO_202601_{member:0>2}_{var}.nc' >
kNN
< f'{os.getcwd()}kNN/kNN_SCEWERO_202601_{member:0>2}_{var}.nc' >
ERA5
< f'{os.getcwd()}kNN/ERA5_SCEWERO_2026-2026_{var}.nc' >
```

S8_GetResults.py

Step 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh

S1_GetERA5.py

S2_ERA5toSCEWERO.py

0 1 2

aragao — -zsh — 80×6

```
aragao@Mac ~ % cd Desktop/SCEWERO/
aragao@Mac SCEWERO % python S8_GetResults.py
```

S8_GetResults.py

Step 8

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kNN PROCESSING

Roadmap to downscale seasonal predictions

SCEWERO

S0_EnvironmentCheck.sh

S1_GetERA5.py

S2_ERA5toSCEWERO.py

0 1 2

aragao — -zsh — 80×6

```
aragao@Mac ~ % cd Desktop/SCEWERO/
aragao@Mac SCEWERO % python S8_GetResults.py
Processing t2m
  jan
  feb
  mar
  apr
  may
  jun
  JFM
  FMA
  MAM
  AMJ
  Daily evolution
  Monthly evolution

Processing t2mn
  jan
  feb
  mar
   ⋮
   ⋮
   ⋮
  Daily evolution
  Monthly evolution

DONE.
aragao@Mac SCEWERO %
```

S8_GetResults.py

Step 8

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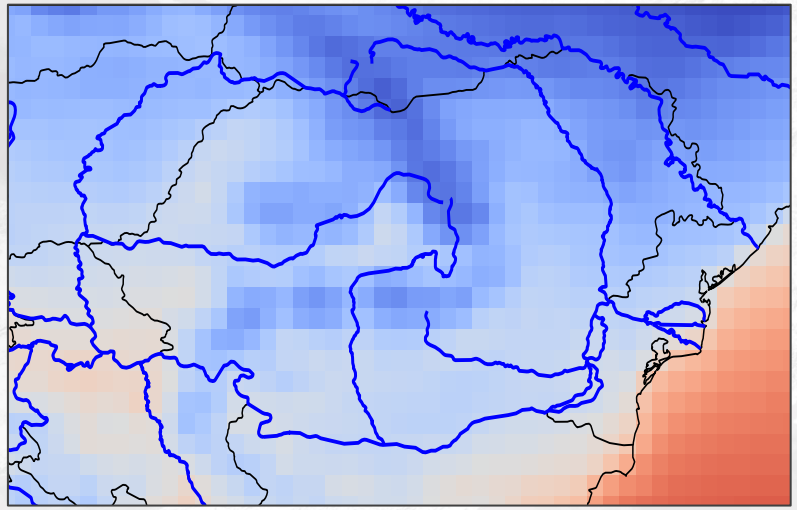
DOWNSCALED FIELDS

DOWNSCALED FIELDS

50 members Ensemble mean of SPS4 issued in December 2025

SCEWERO

ERA5



Daily average 2m temperature **T2M** (°C) at lead month 1 (January 2026)



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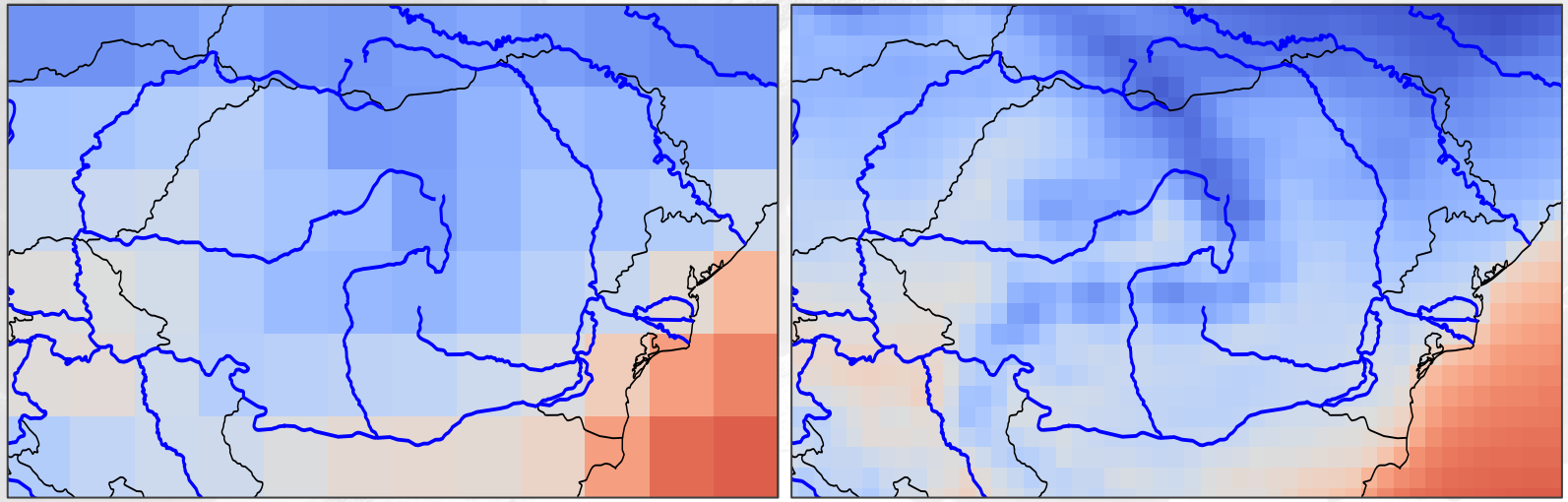
DOWNSCALED FIELDS

50 members Ensemble mean of SPS4 issued in December 2025

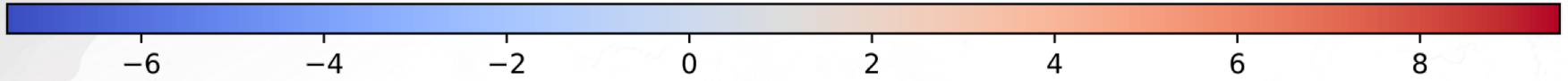
SCEWERO

SPS

ERA5



Daily average 2m temperature **T2M** (°C) at lead month 1 (January 2026)



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DOWNSCALED FIELDS

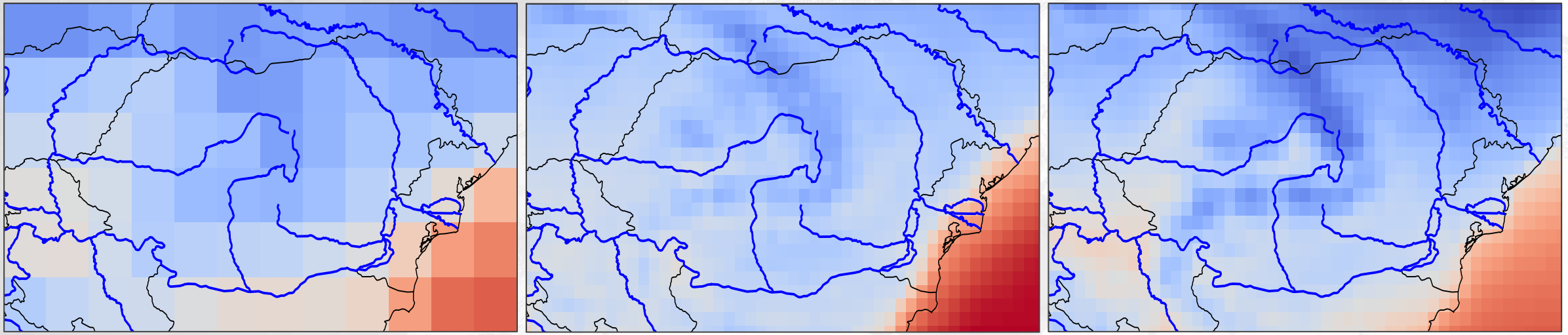
50 members Ensemble mean of SPS4 issued in December 2025

SCEWERO

SPS

*k*NN

ERA5



Daily average 2m temperature **T2M** (°C) at lead month 1 (January 2026)



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DOWNSCALED FIELDS

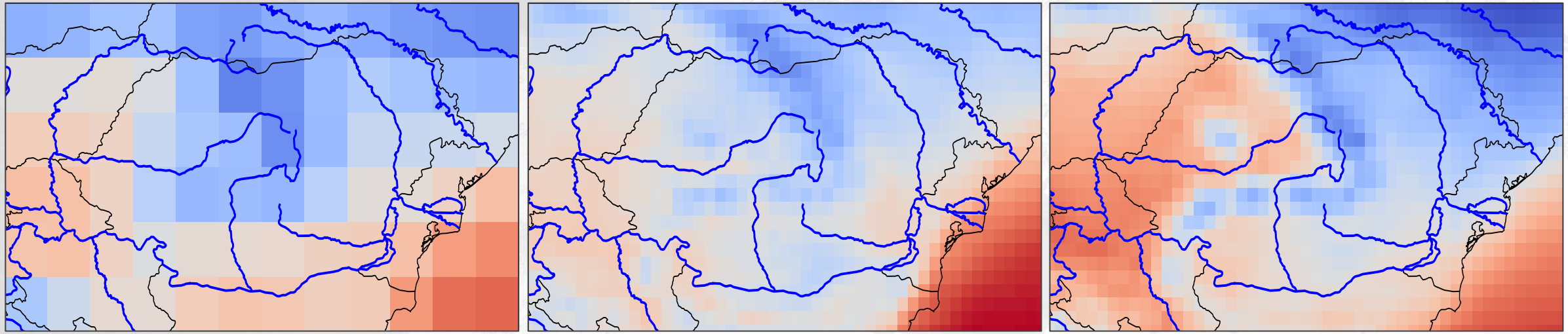
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Daily average 2m temperature **T2M** (°C) at lead month 2 (February 2026)



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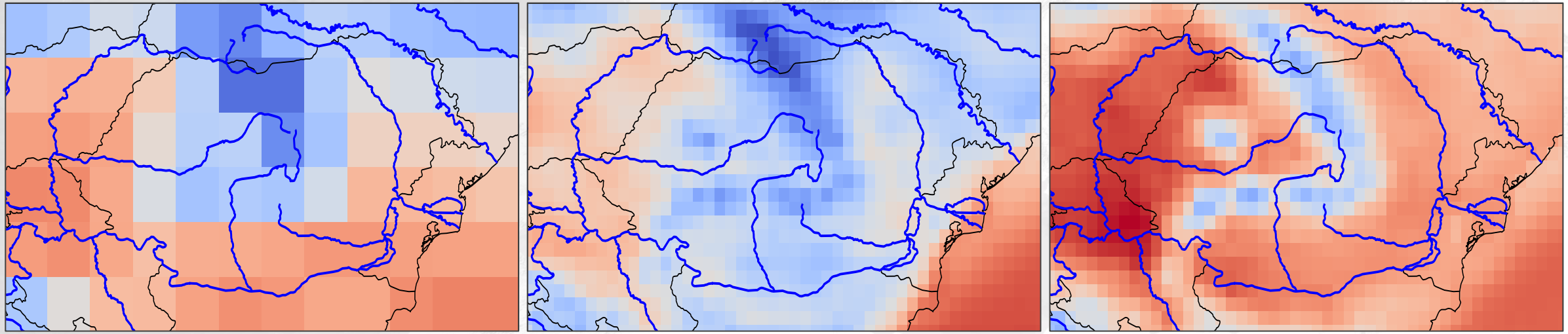
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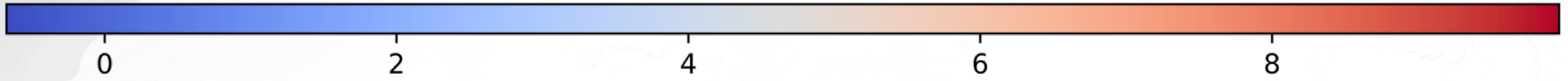
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Daily average 2m temperature **T2M** (°C) at lead month 3 (March 2026)



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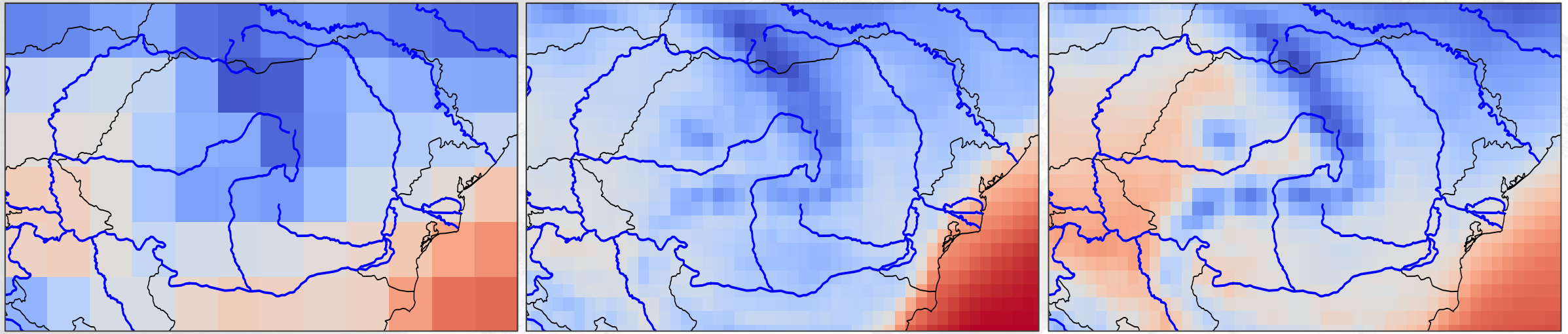
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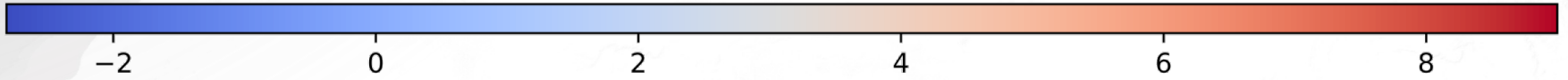
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Daily average 2m temperature **T2M** (°C) at lead season 1 (JFM 2026)

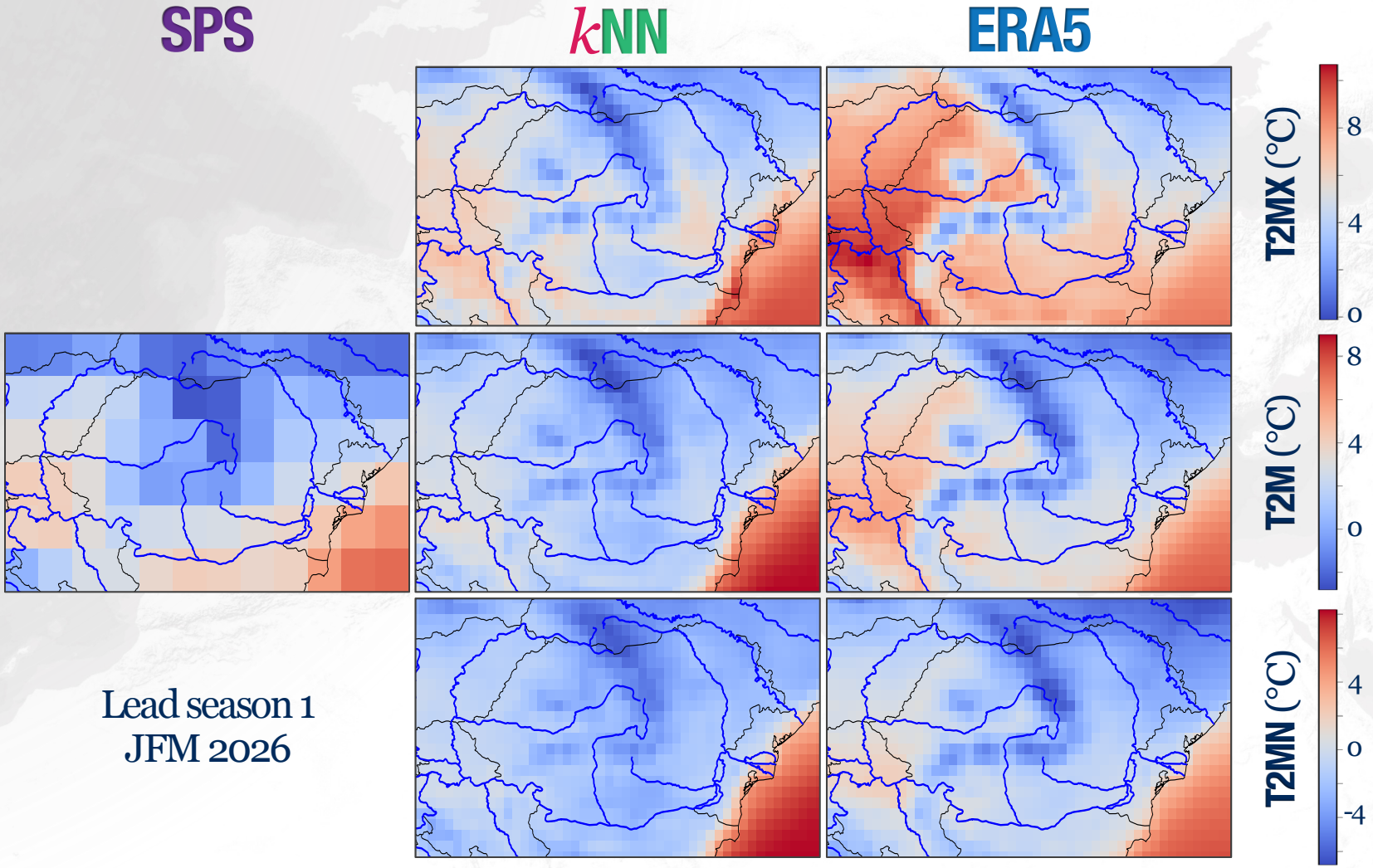


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Lead season 1
JFM 2026

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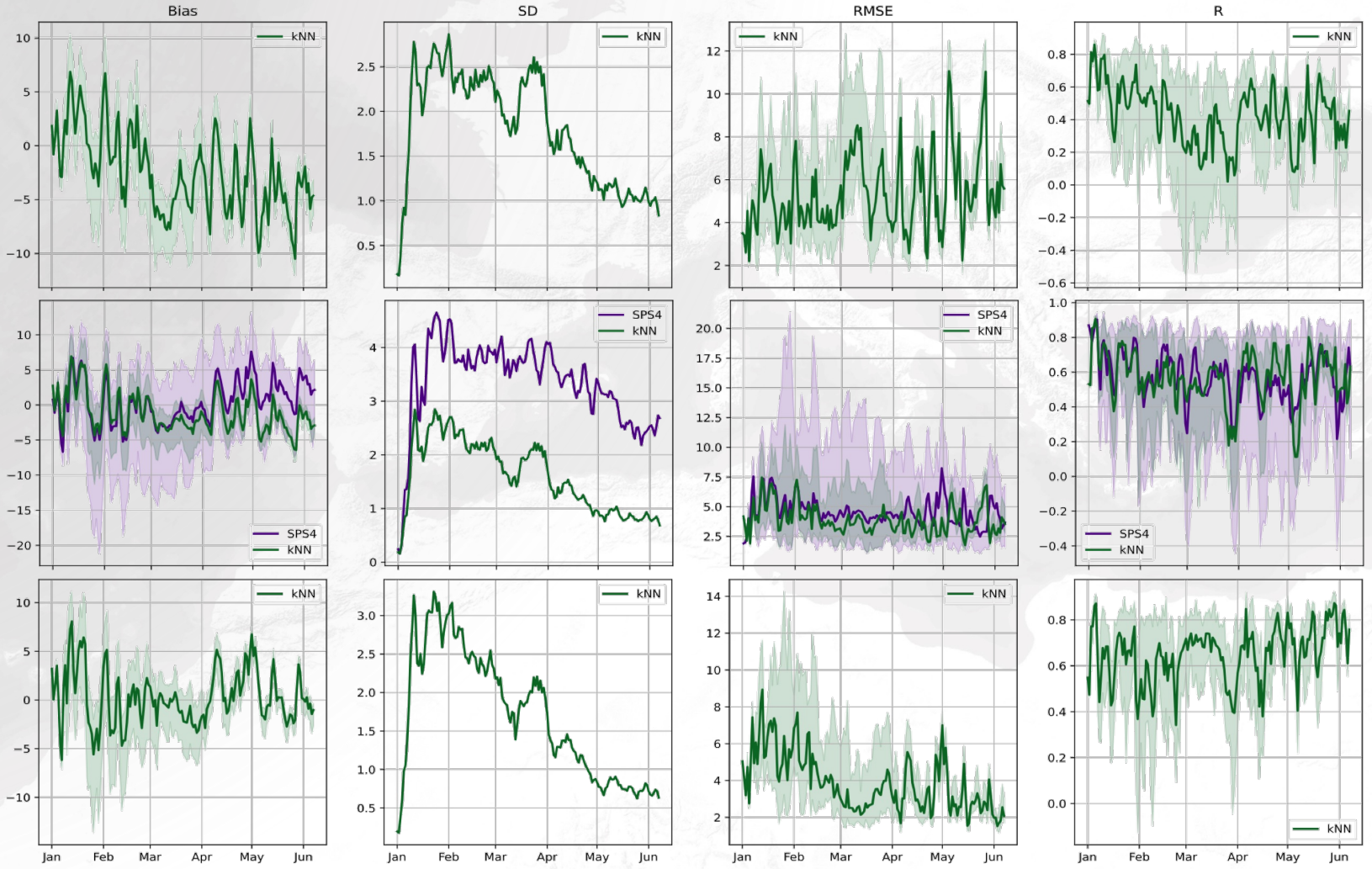
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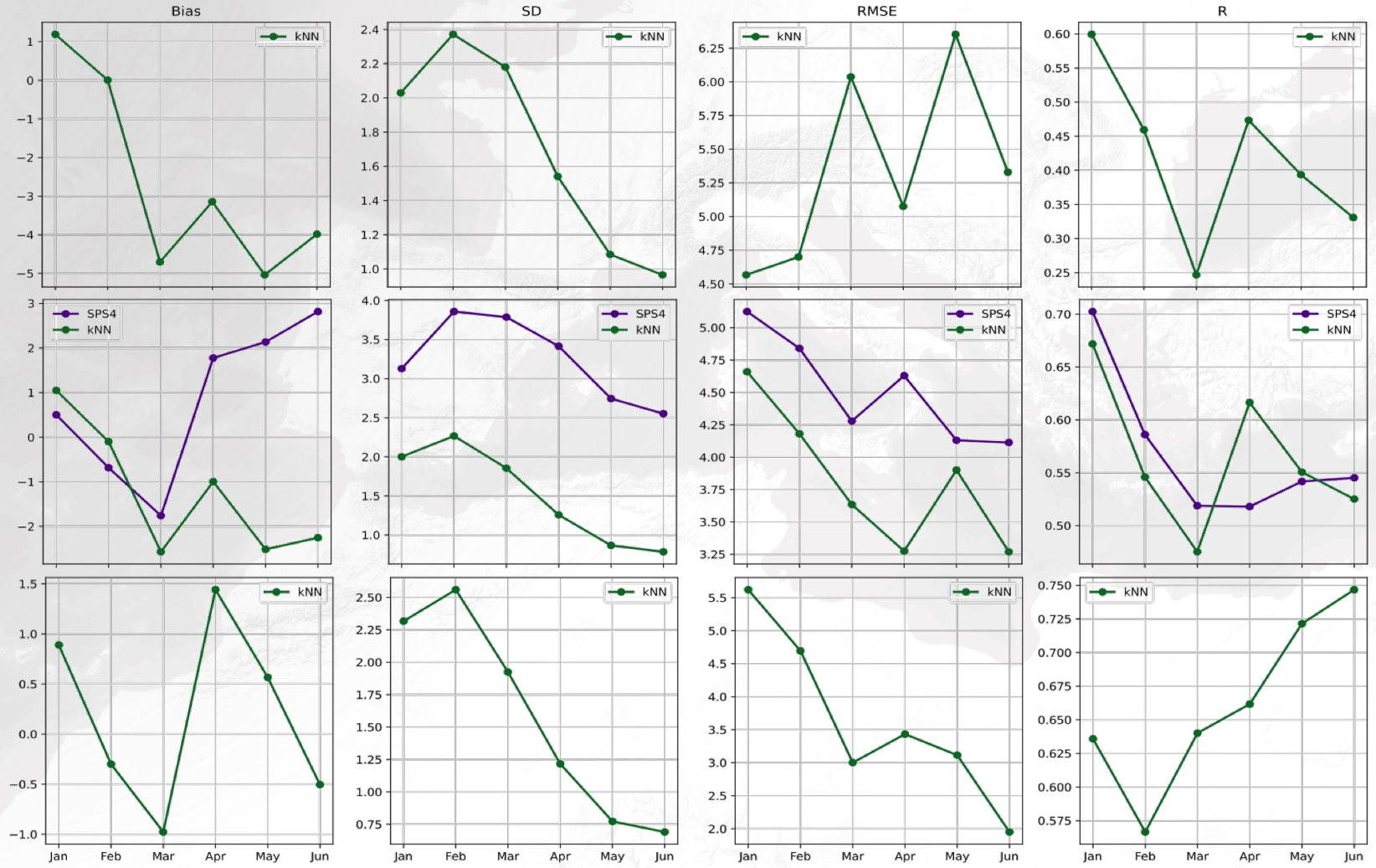
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STRENGTHENING THE RESEARCH CAPACITIES
FOR EXTREME WEATHER EVENTS IN ROMANIA

TRAINING ON AI USE FOR CLIMATE EXTREMES 2026

STATISTICAL DOWNSCALING USING MACHINE LEARNING TECHNIQUES

Hands-on k-Nearest Neighbours to extend seasonal forecast applications to the local scale

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Leonardo Aragão

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Thank you!

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