



Co-funded by the  
Erasmus+ Programme  
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ClimEd Project “Multilevel Local, Nation-  
and Regionwide Education and Training in Climate  
Services, Climate Change Adaptation and Mitigation”



# GIS Applications in Climate Services

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O. M. Beketov National University of Urban Economy in Kharkiv, Ukraine

ClimEd 7th Training (onsite/ hybrid)

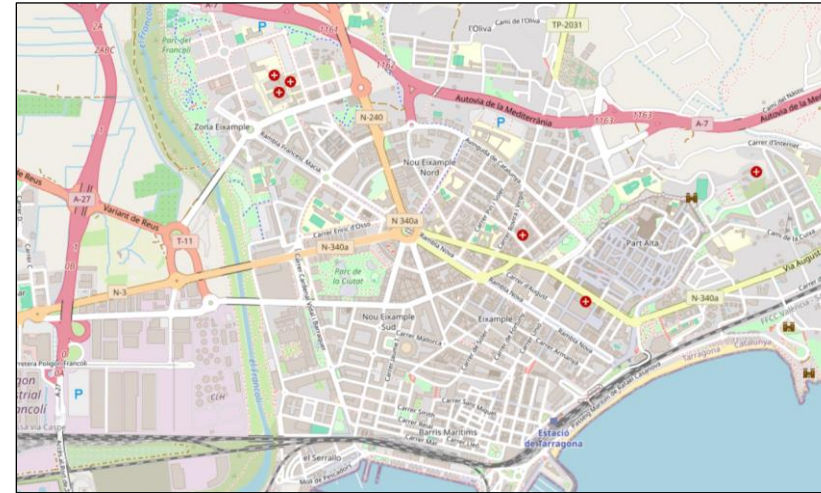
Developing Skills to Use Climatic Information and Services for Various Climate-Dependent Branches of Economy

7-11 April 2025

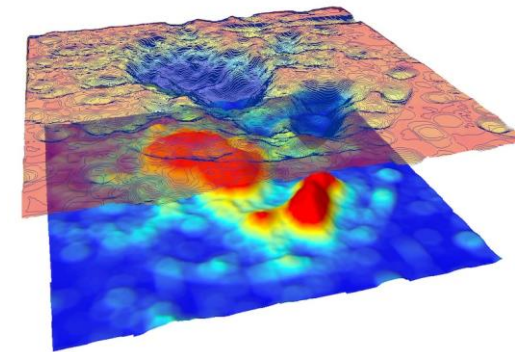
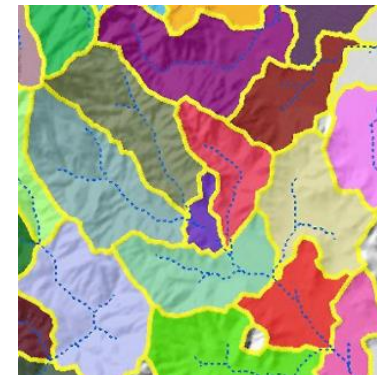
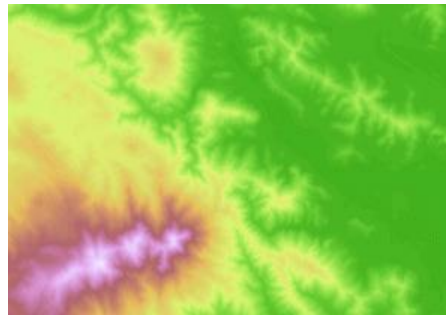
Vila-Seca, Tarragona, Spain

# Why do we apply Geographical Information Systems – GIS?

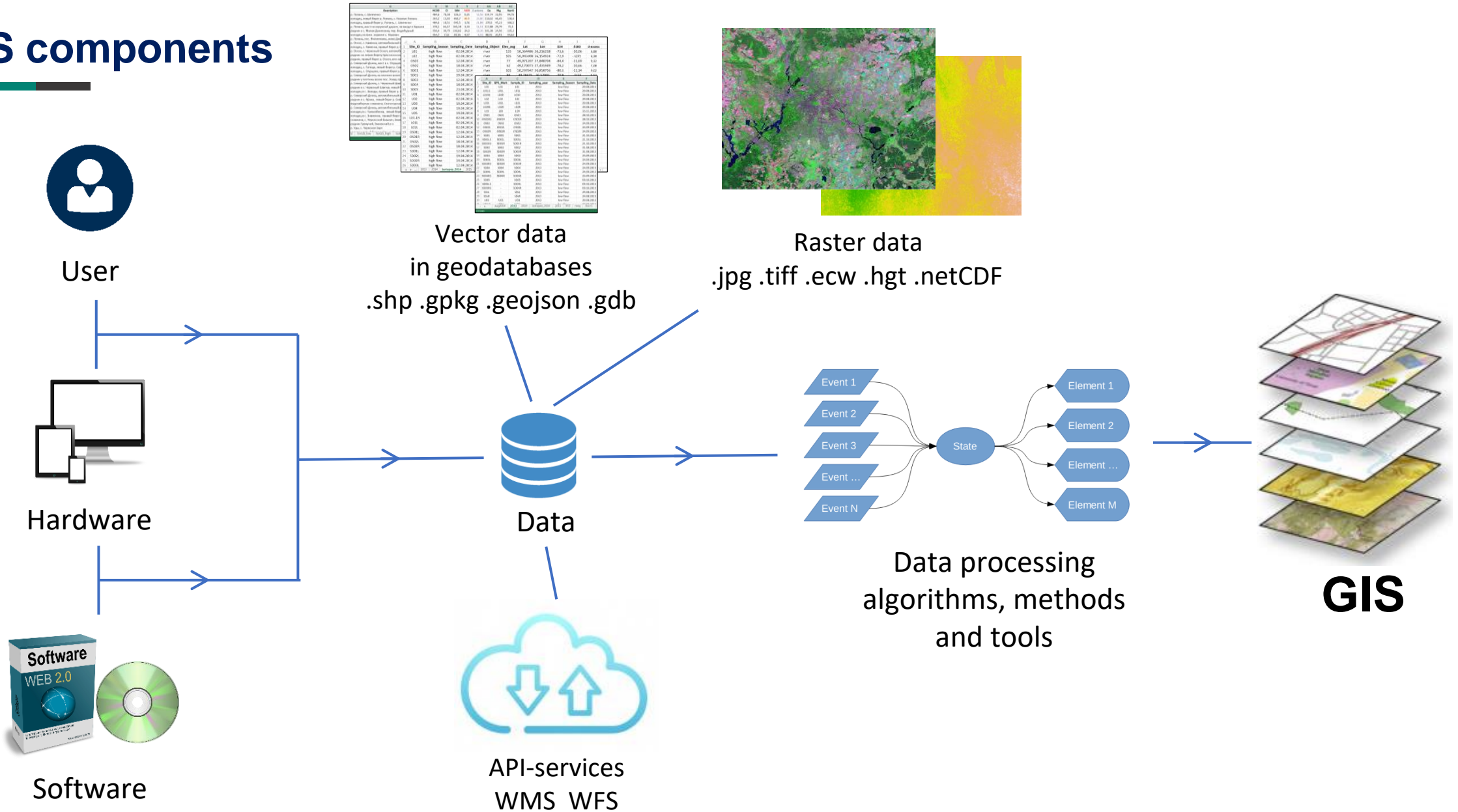
Simulation and visualization  
of real world – mapping



Geospatial analysis  
and modelling



# GIS components



# GIS software

## Desktop GIS applications

ArcGIS  esri



ArcGIS Pro

<https://www.esri.com/en-us/home>



QGIS

<https://qgis.org/download/>

## Web-GIS applications

ArcGIS  esri



ArcGIS Online

<https://www.arcgis.com/index.html>

ArcGIS  esri



ArcGIS Earth

<https://www.esri.com/en-us/arcgis/products/arcgis-earth/overview>

Google Earth Pro



<https://www.google.com/earth/about/>

OpenStreetMap



<https://www.openstreetmap.org>



# Climate data in GIS



## What is special about climate data?

- continuous in space and time
- global to local scales
- diversity of climate indicators
- majority of indicators are derived from other indicators

**Climate data = Big data**

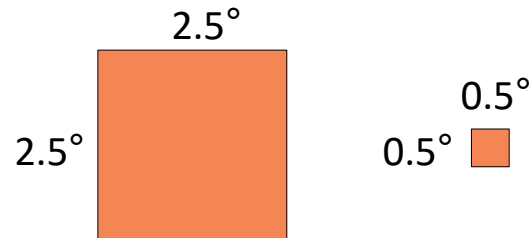
## Data massiveness is a challenge

- historical, future, calculated change
- hourly / daily / monthly / annual timescales
- sources – observations, reanalysis, modelling
- up to 10 basic climate indicators and numerous ones derived from
- 120+ climatic models
- up to 5 GHG emission future scenarios
- uncertainty and incompleteness issues

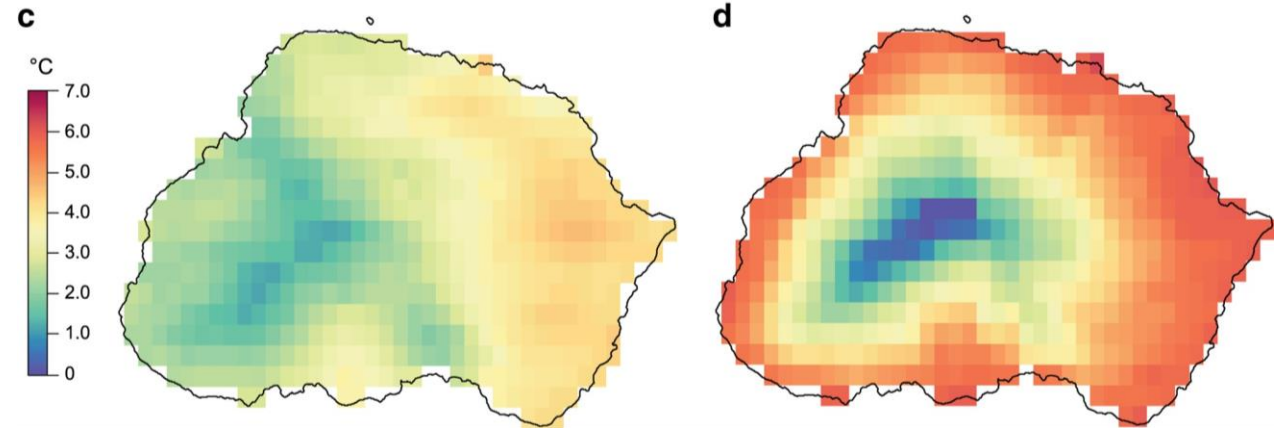
# Climate data in GIS

In GIS, climate data are stored as **raster data** (.geotiff, ....)

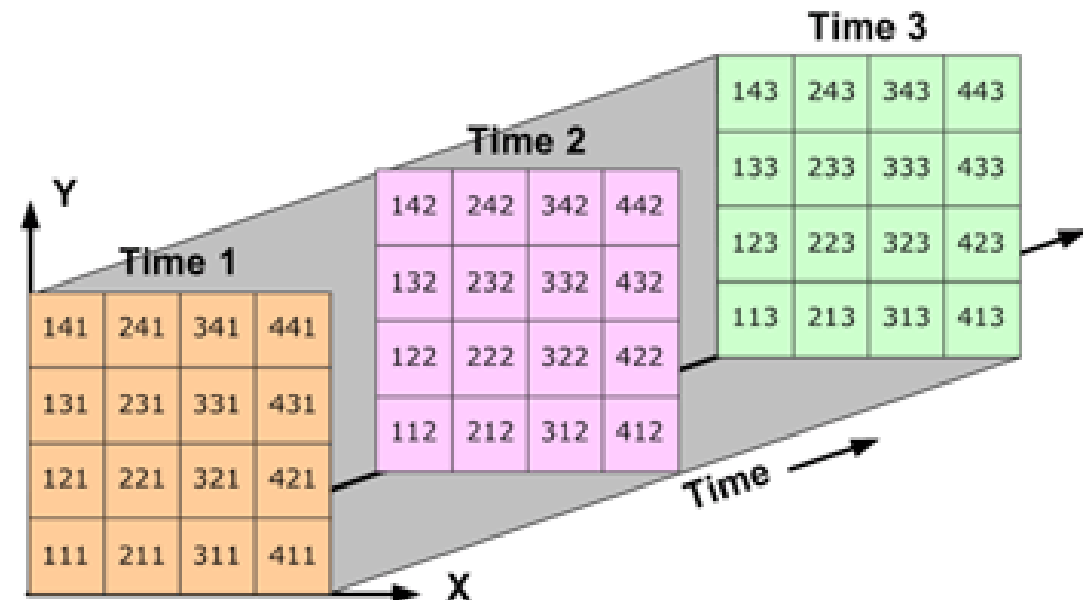
**Spatial resolution** varies from 2.5 degrees (coarse) to 0.5 degree (fine)



Multidimensional rasters **NetCDF** (Network Common Data Form) – for massive climate data storage



<https://www.nature.com/articles/sdata2018177/figures/1>



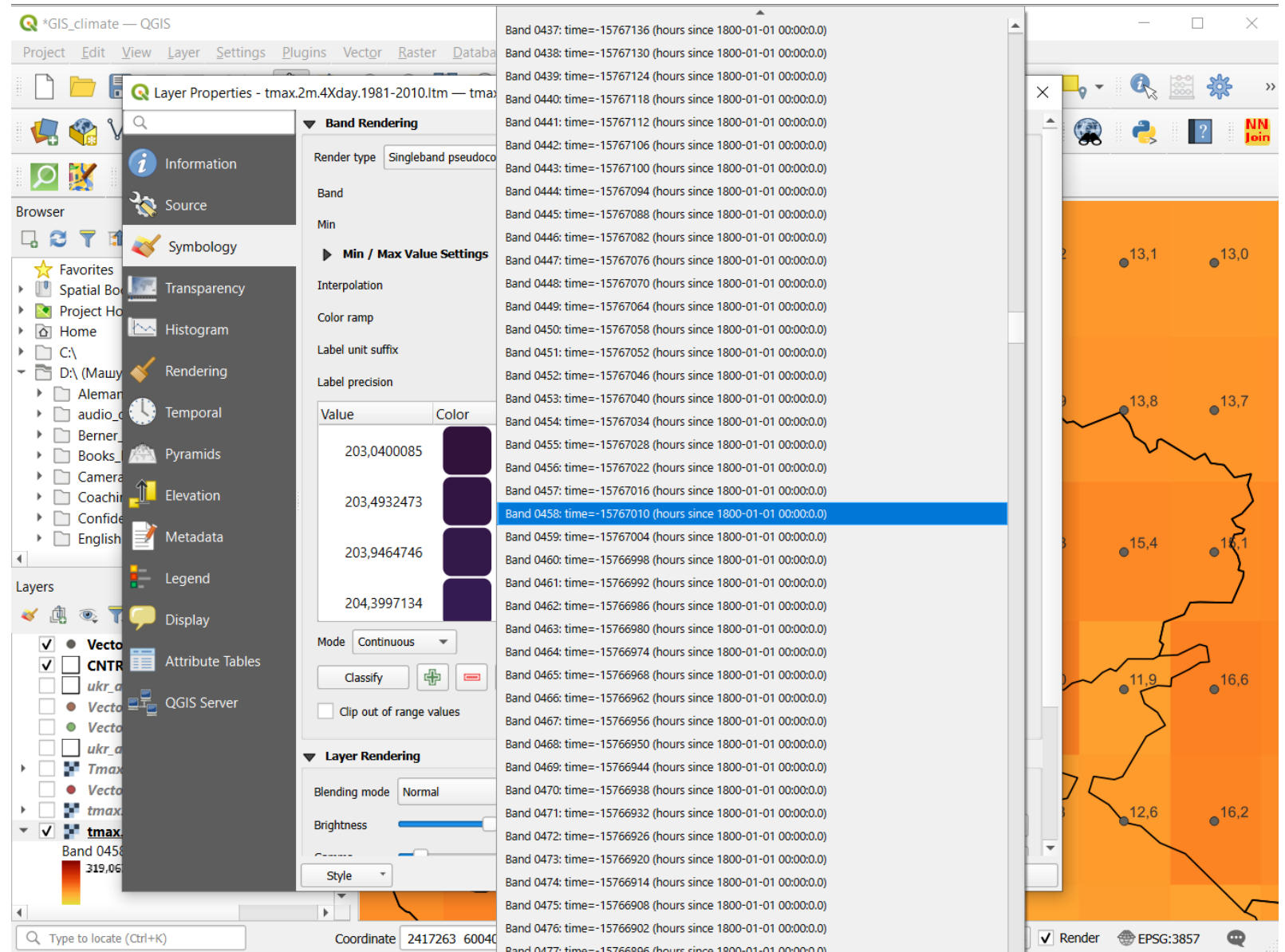
<https://desktop.arcgis.com/en/arcmap/latest/manage-data/netcdf/fundamentals-of-netcdf-data-storage.htm>

# Climate data in GIS

Single NetCDF file can store several **variables** (i.e. min, mean and max temperature) in **dimensions** of time (i.e. daily for 30 years) and space (X, Y)

Each time band of each variable can be extracted as a separate raster layer.

All layers in NetCDF rasters can undergo calculations in **Raster calculator** to generate new rasters (i.e. to calculate the difference between mean temperature of past and future)



# How to handle climate geodata?



## **Ready-to-use web-applications**

- Maps and dashboards in a web-browser providing climate data generation and visualization
- Easy tools to customize general options – area or point location, selection for timeframes, indicators, scenarios
- No need of GIS skills

## **Geodata download portals**

- Flexible system of climate indicators and other options/criteria selection
- A portal may have certain limitations regarding your requirements
- Needs for GIS software and basic skills in geodata visualisation

## **Development of your own rasters**

- Full freedom in developing climate indicators, areas and time frames
- Reasonable for local and regional scales
- Needs for deep knowledge and advanced skills in GIS

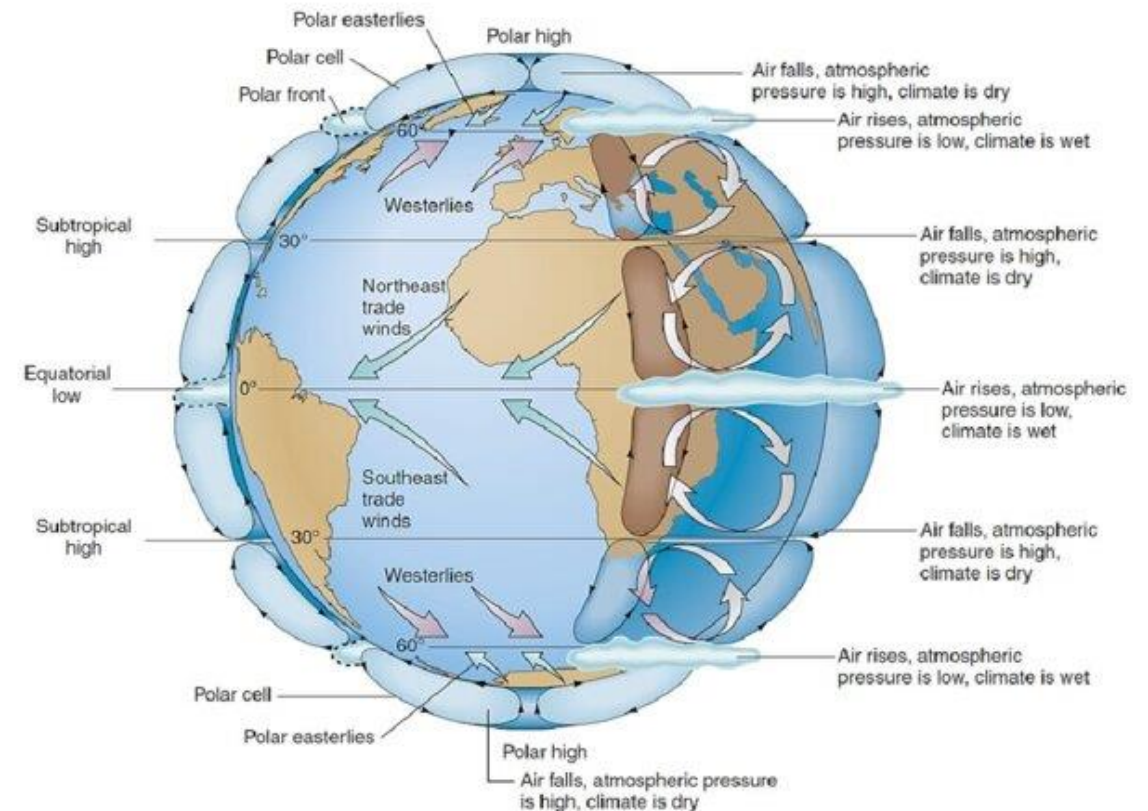
# GIS application in climate science

## Global circulation modeling (GCM)

- Simulate climate processes globally at different levels in the atmosphere and oceans
- Long-term modelling of past, present and future climate
- Spatial resolution 1.0 – 2.5 degrees

### Leading GCM developers

Institution	Model Name	Country
NASA GISS	GISS-E2	USA
NOAA GFDL	GFDL-CM4, GFDL-ESM4	USA
NCAR (CESM)	CESM	USA
UK Met Office Hadley Centre	HadGEM3, UKESM1	UK
ECMWF	EC-Earth	Europe
IPSL	IPSL-CM6A-LR	France
MPI-M	MPI-ESM1.2	Germany
CMCC	CMCC-CM2	Italy
BCC	BCC-CSM2-MR	China
MRI-JMA	MRI-ESM2.0	Japan





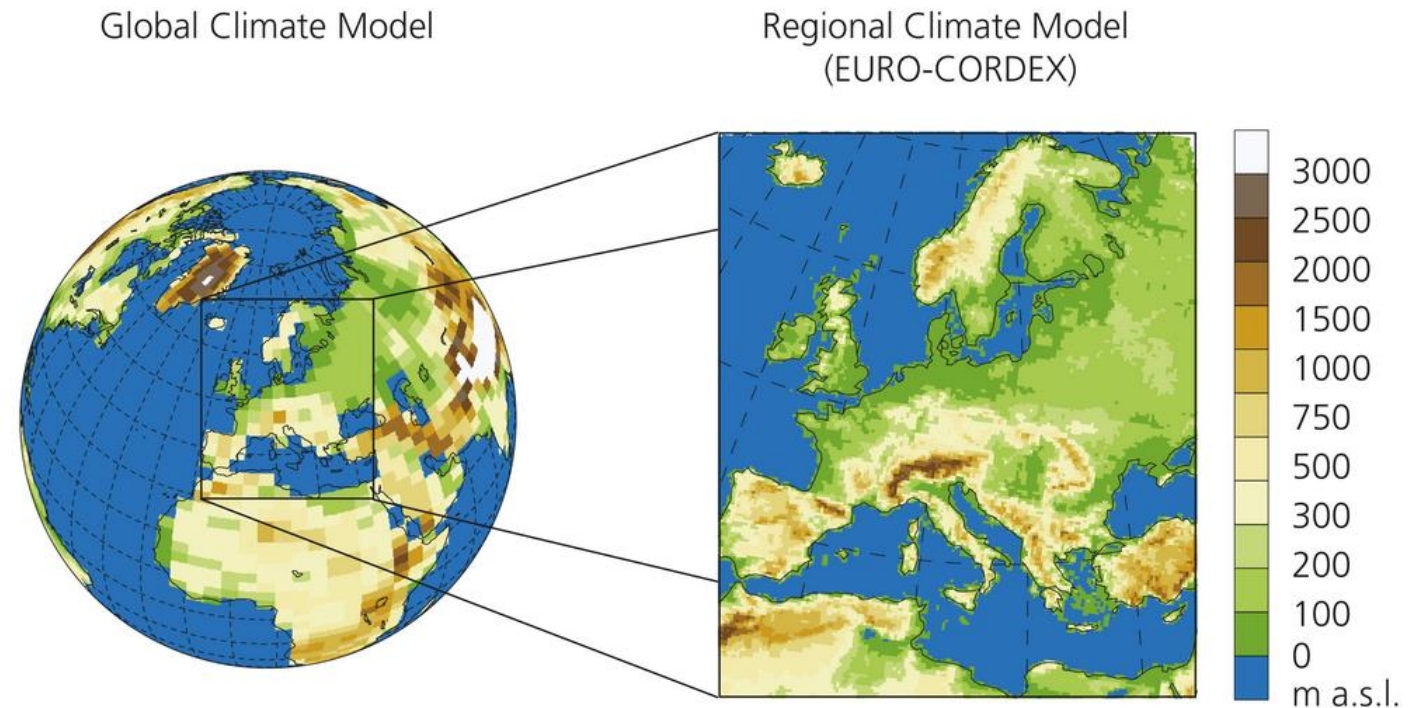
# GIS application in climate science

## Regional circulation modeling (RCM)

- Downscaled from GCM considering local topography, land use, vegetation and other
- Represent local effects and impacts of climate
- Spatial resolution 0.1 – 0.5 degrees and finer

### Leading RCM developers

Institution	Model Name	Country
ICTP	RegCM	Italy
UK Met Office	PRECIS	UK
SMHI	RCA4	Sweden
CLM-Community	COSMO-CLM	Germany
NCAR	WRF	USA
EURO-CORDEX Consortium	RCA4, CLMcom, ALADIN, WRF, HIRHAM, and more	EU countries



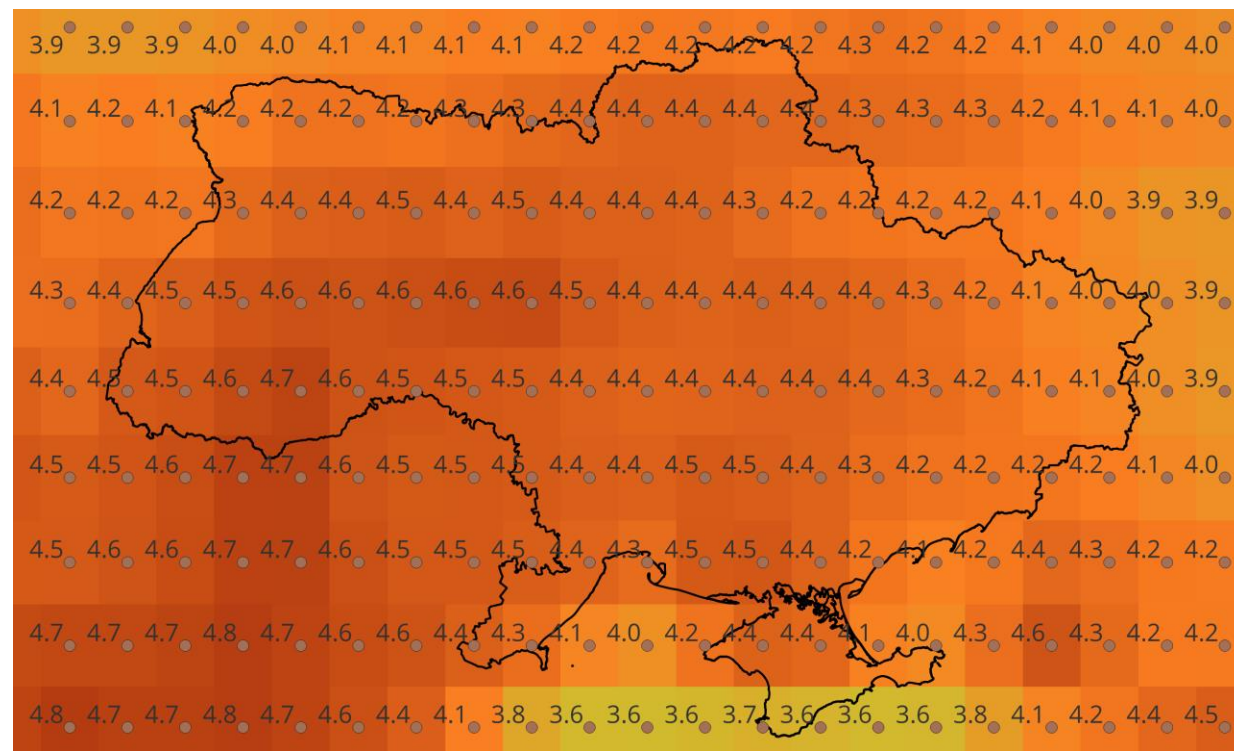
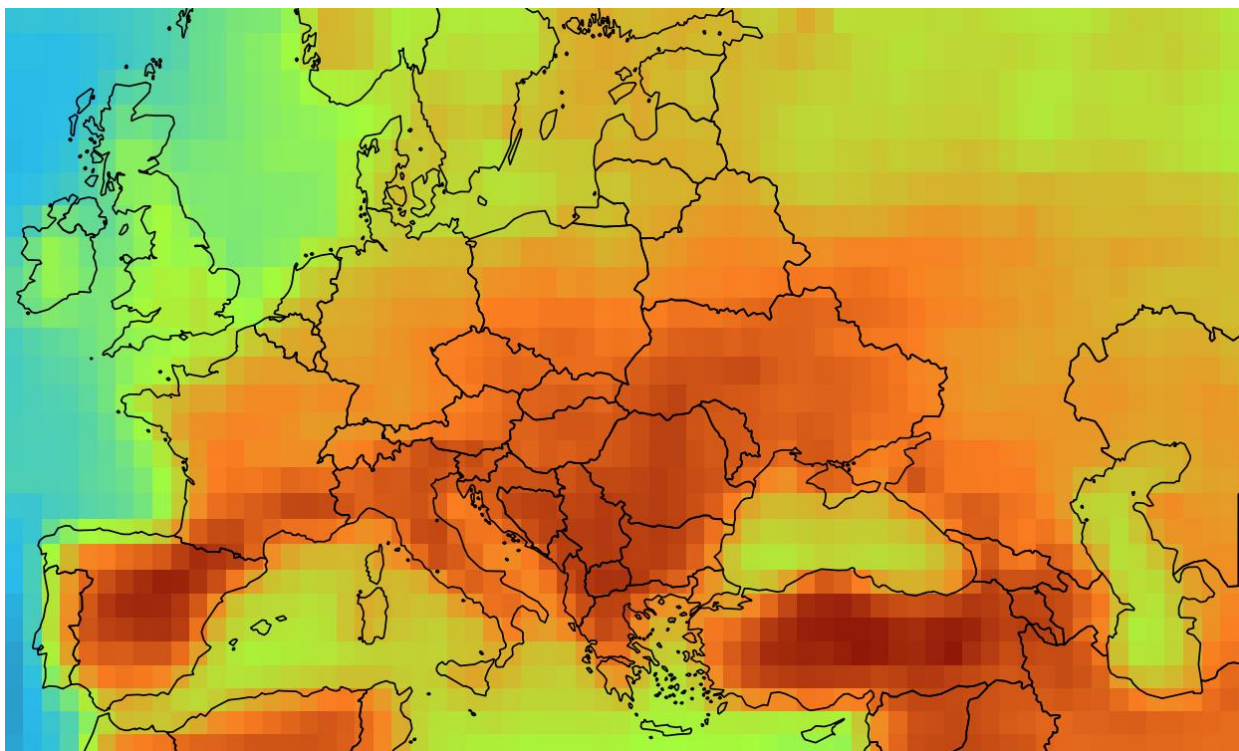


# How does spatial resolution matter?

## Global Climate Models (GCMs)

Resolution range: 100–250 km (low-resolution)

Maximum of daily maximum temperature (°C) - CMIP6 - Change - rel. to 1850-1900 - SSP5-8.5 - (2041-2060) - Annual



Spatial resolution – 1.0 x 1.0 degrees (76 km x 110 km in WGS 84 / Pseudo-Mercator projection)

# How does spatial resolution matter?

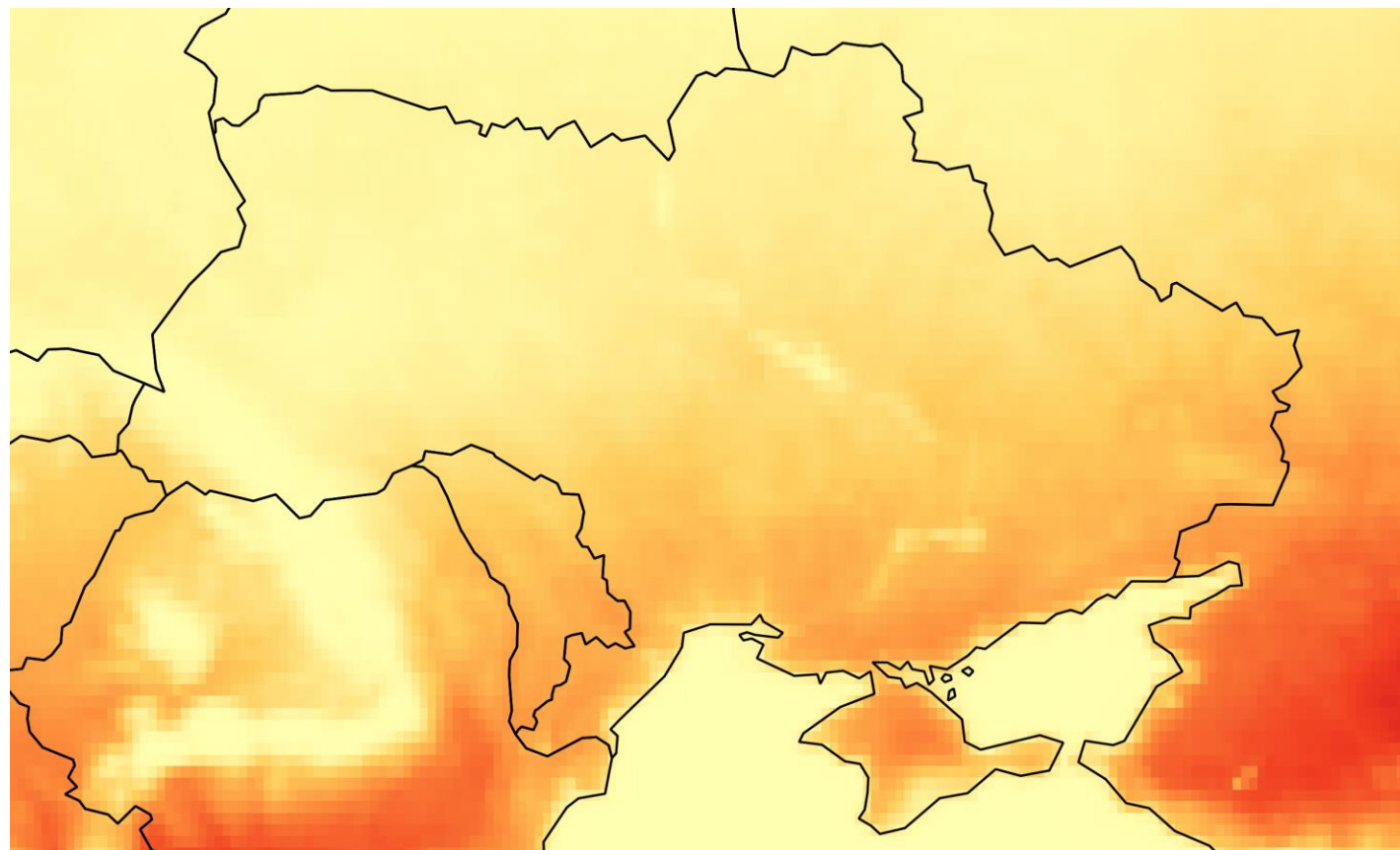
## Regional Climate Models (RCMs)

Days with maximum temperature above 35 °C (days) - CORDEX-EUR-11 - Change - rel. to 1981-2010 - RCP4.5 - (2041-2060) - Annual

Resolution range: 10–50 km  
(medium-resolution)

CORDEX (Coordinated  
Regional Climate  
Downscaling Experiment)

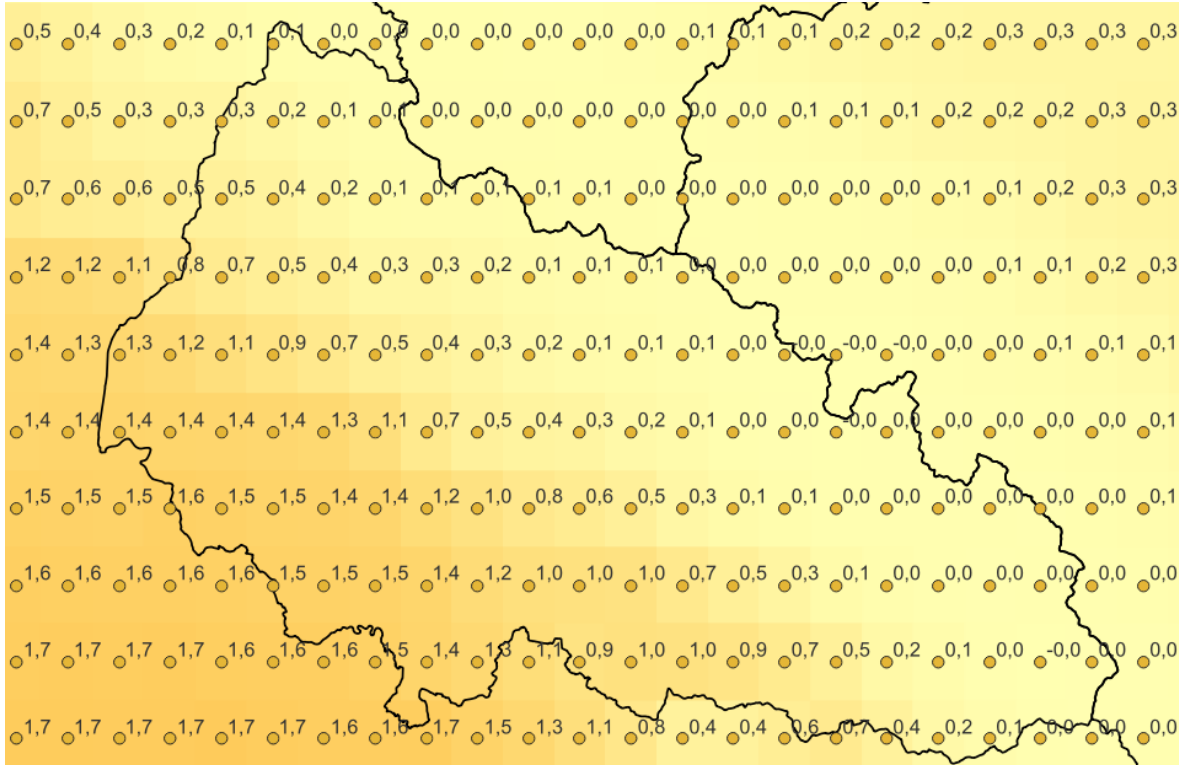
0.1 x 0.1 degrees  
9 x 14 km  
(in WGS 84 / Pseudo-  
Mercator projection)



# How does spatial resolution matter?

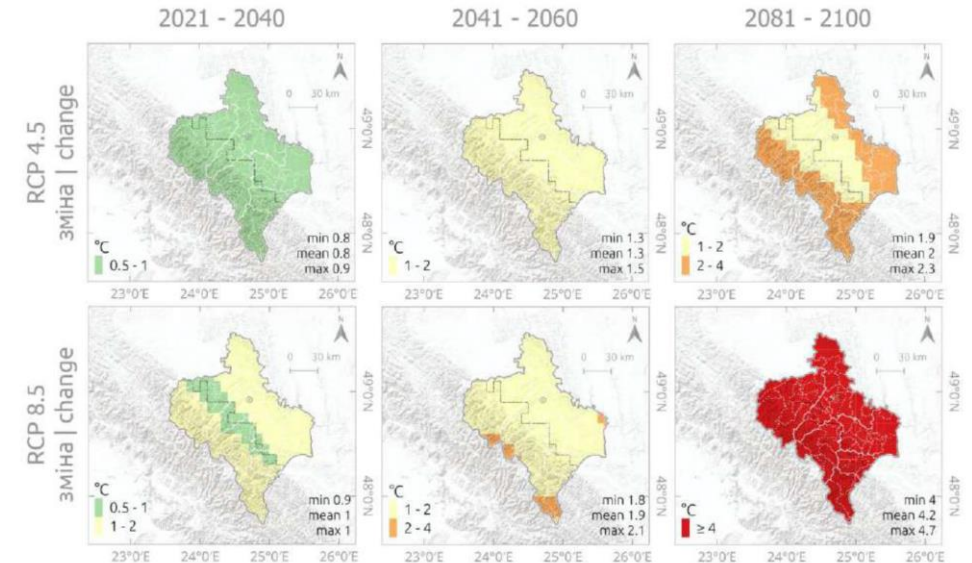
## Zakarpatska oblast

Days with maximum temperature above 35 °C (days) - CORDEX-EUR-11 - Change - rel. to 1981-2010 - RCP4.5 - (2041-2060) - Annual



Data source: <https://atlas.climate.copernicus.eu/atlas>

## Ivano-Frankivska oblast



Data source: Climate change adaptation strategy for Ivano-Frankivsk region, 2024 (in Ukrainian)

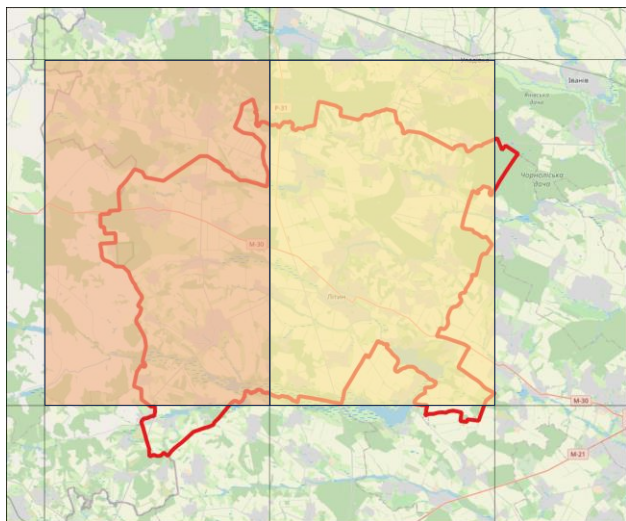
Resolution of 0.1 x 0.1 degrees (9 x 14 km) is suitable for national and regional (oblast) scales.

RCMs with such resolution are particularly effective in oblasts with rugged terrain like the Carpathian mountainous area.



# How does spatial resolution matter?

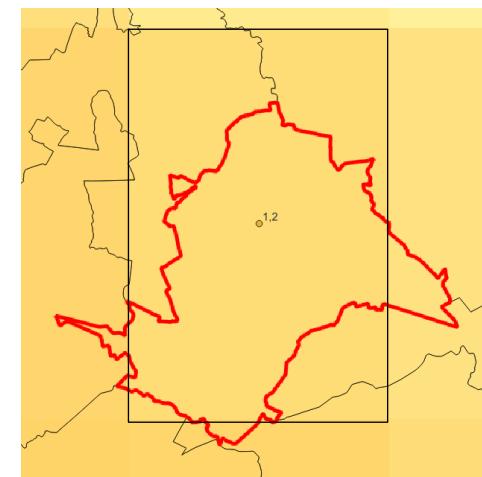
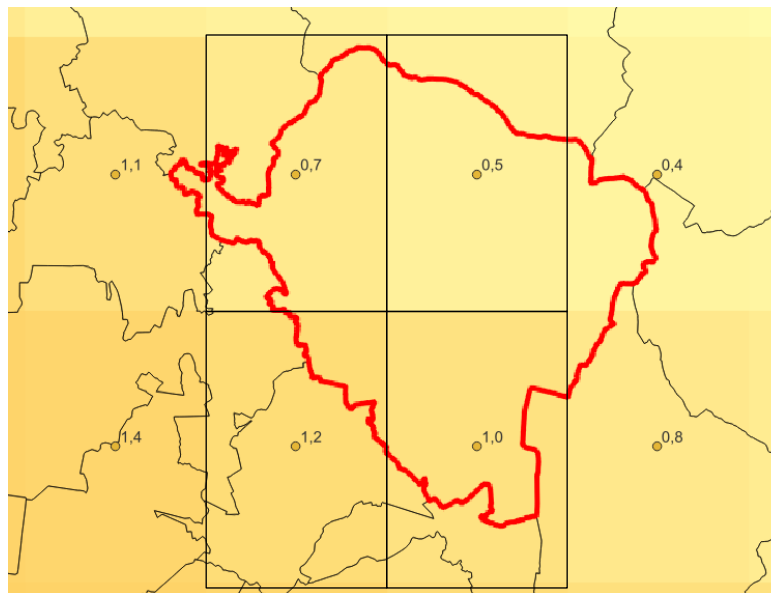
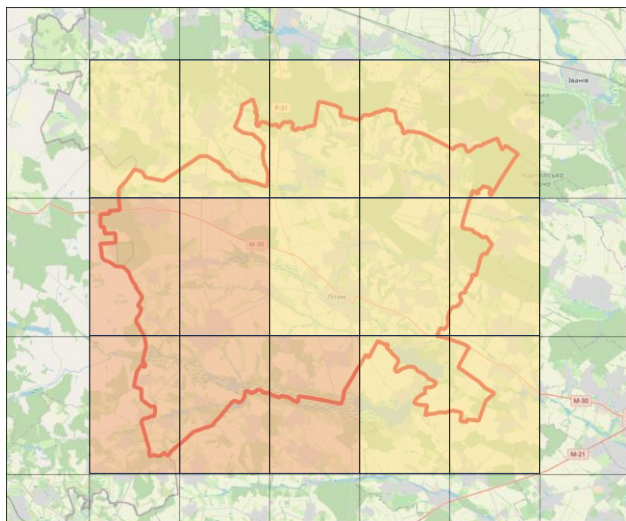
**0.25 x 0.25  
degrees**



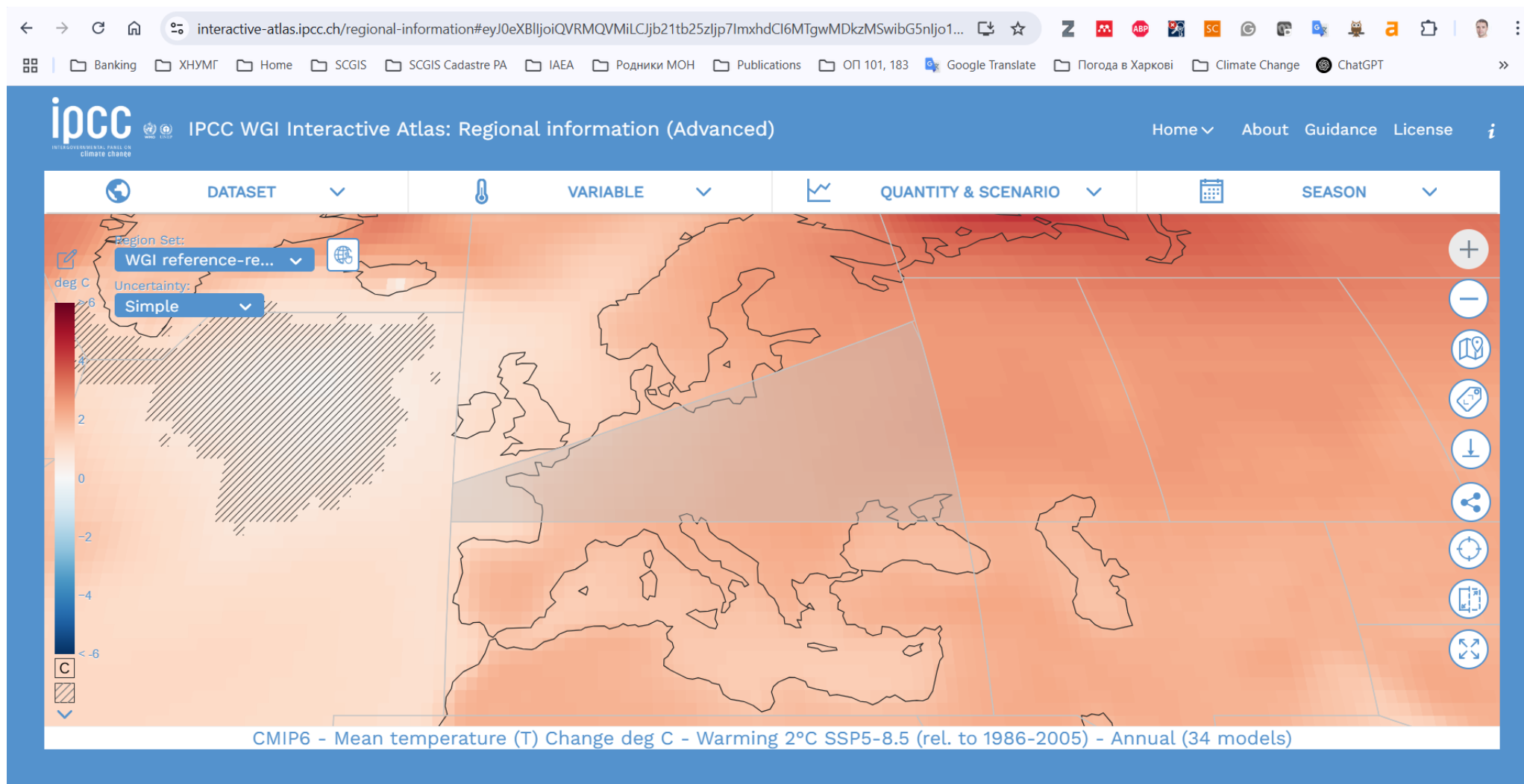
For the local community level, the resolution of 0.1 x 0.1 degrees (9 x 14 km) may be reasonable if the community area is relatively large.

For relatively small areas further downscaling is needed – up to 30 seconds (1 km<sup>2</sup>).

**0.1 x 0.1  
degrees**



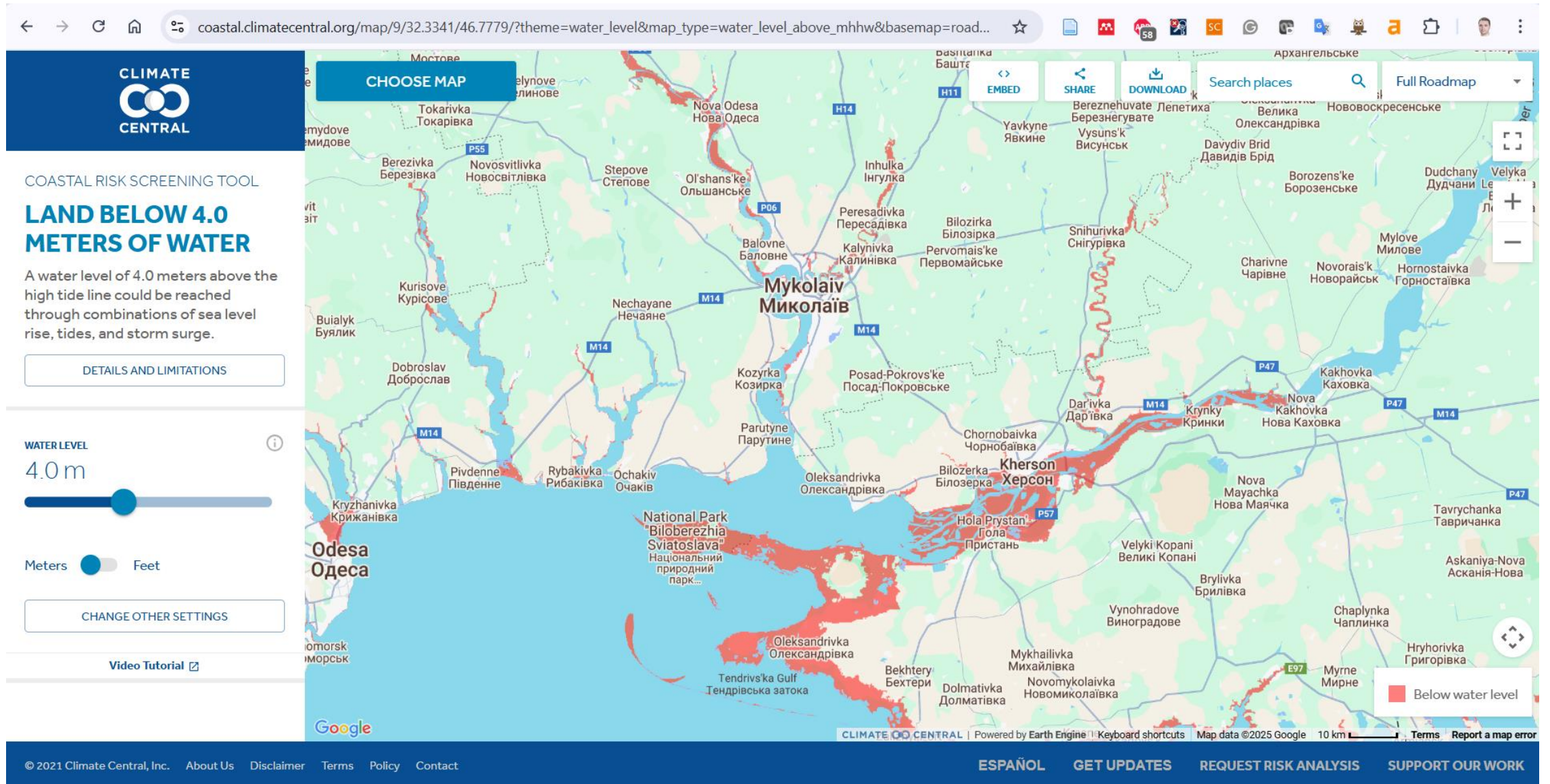
# Ready-to-use GIS web-applications: IPCC WGI Interactive Atlas



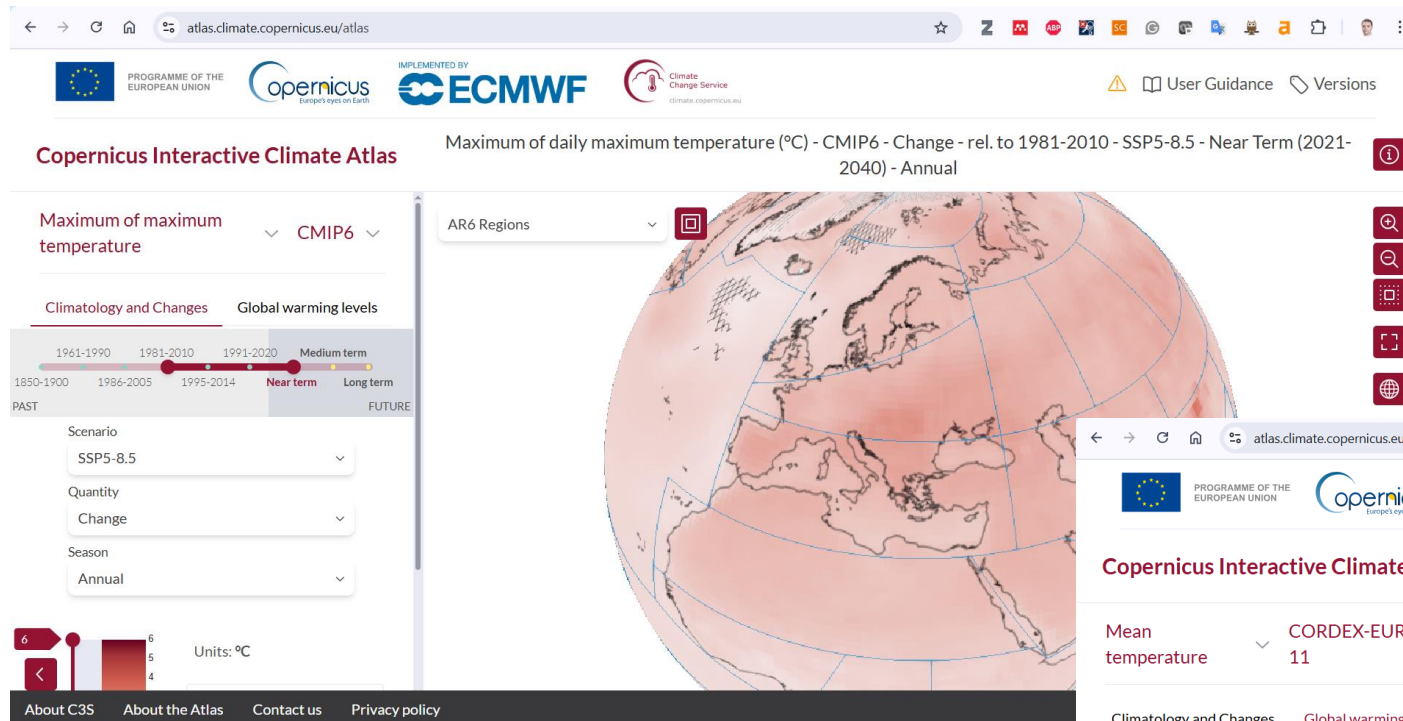




# Ready-to-use GIS web-applications: coastal risk screening tool

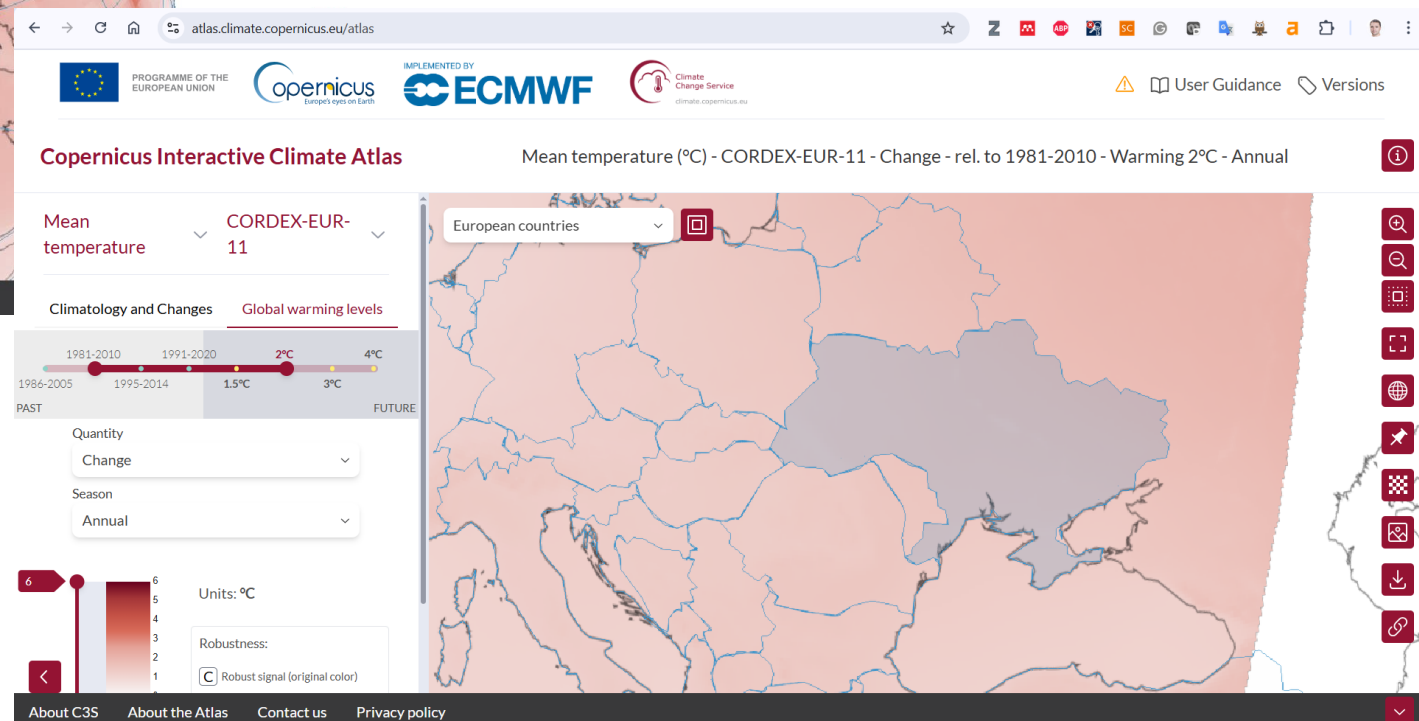


# Portals for downloading raster climate data: Copernicus Interactive Climate Atlas

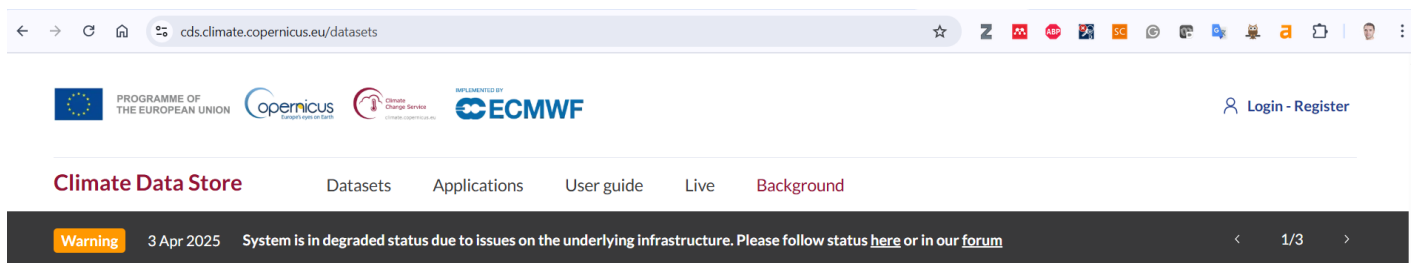


<https://cds.climate.copernicus.eu/>

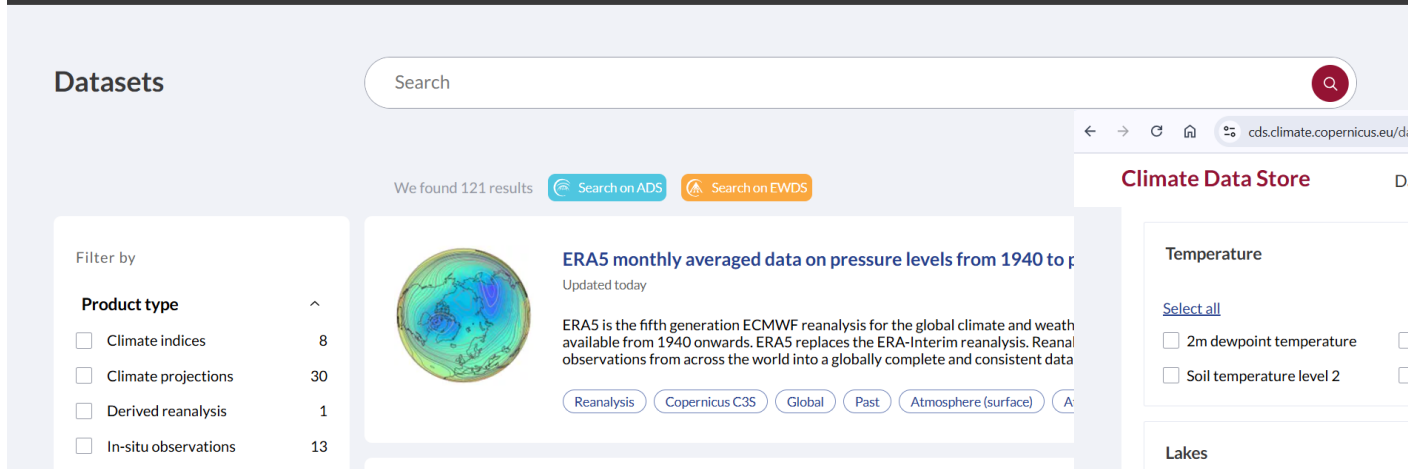
- Allows to obtain calculated changes between past, present and future climate data
- Convenient system of parameters selection
- NetCDF and GeoTIFF formats are available



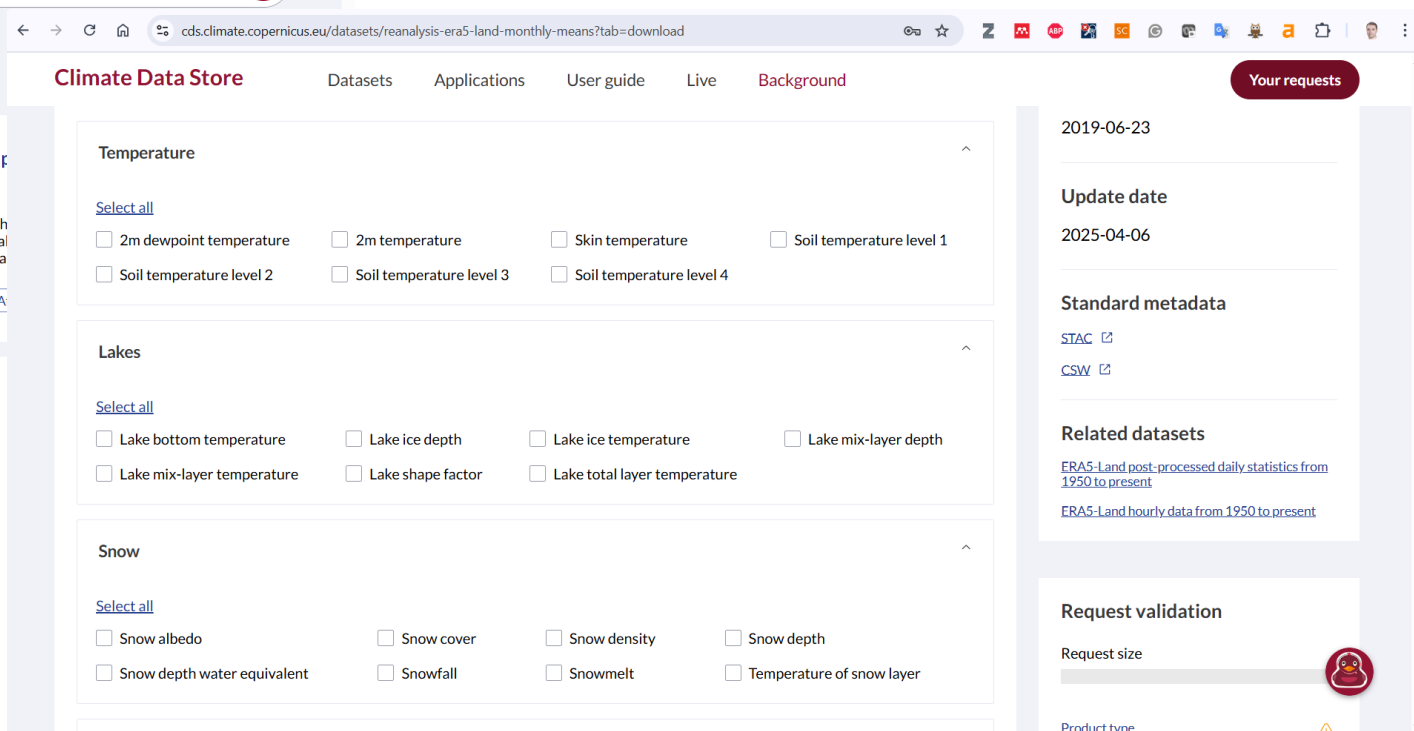
# Portals for downloading raster climate data: Climate Data Store



- Vast list of climate variables and time frames
- Flexible system of parameters selection
- NetCDF format is available

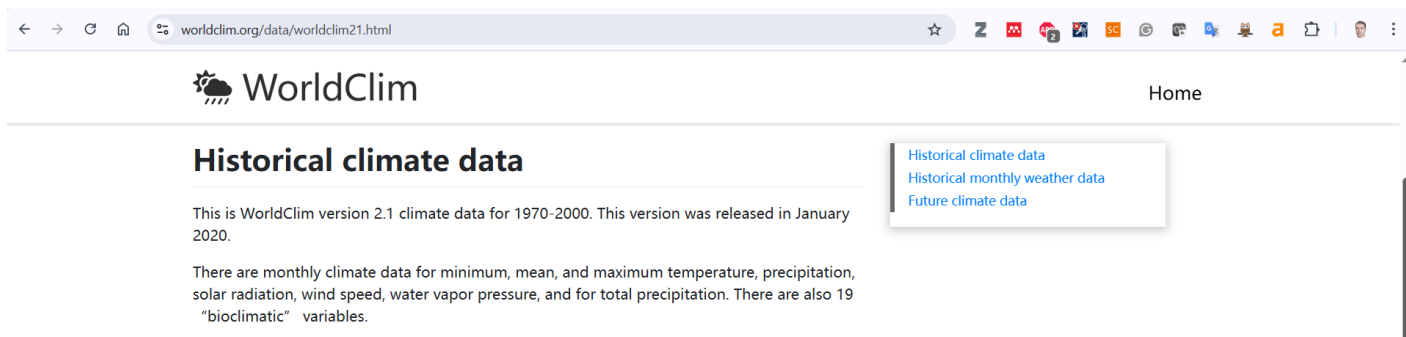


<https://cds.climate.copernicus.eu/>





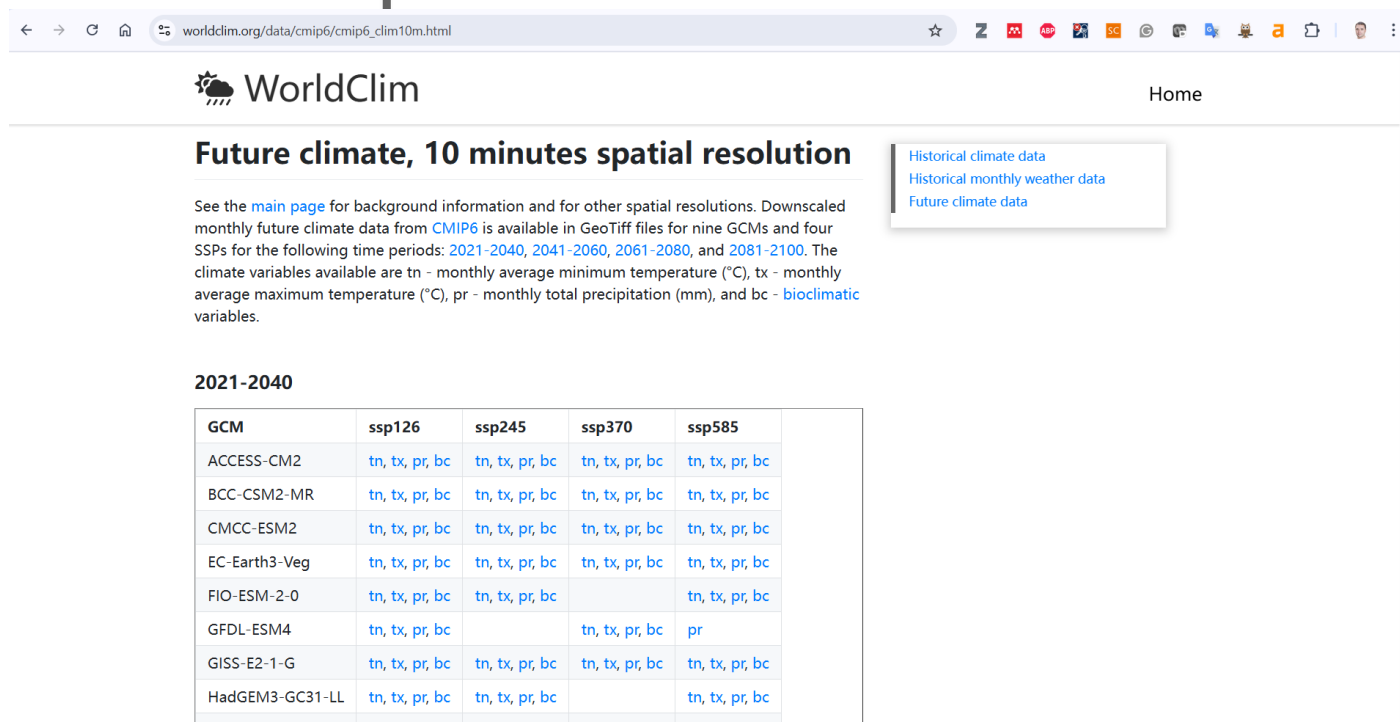
# Portals for downloading raster climate data: WorldClim



The screenshot shows the WorldClim website's 'Historical climate data' page. The page title is 'Historical climate data'. Below the title, it states: 'This is WorldClim version 2.1 climate data for 1970-2000. This version was released in January 2020.' It then lists the variables available: 'There are monthly climate data for minimum, mean, and maximum temperature, precipitation, solar radiation, wind speed, water vapor pressure, and for total precipitation. There are also 19 "bioclimatic" variables.' It also mentions the spatial resolutions: 'The data is available at the four spatial resolutions, between 30 seconds (~1 km2) to 10 minutes (~340 km2). Each download is a "zip" file containing 12 GeoTiff (.tif) files, one for each month of the year (January is 1; December is 12).' A table is provided below the text, showing the variables and their corresponding file names for each spatial resolution. A sidebar on the right contains links: 'Historical climate data', 'Historical monthly weather data', and 'Future climate data'.

variable	10 minutes	5 minutes	2.5 minutes	30 seconds
minimum temperature (°C)	<a href="#">tmin 10m</a>	<a href="#">tmin 5m</a>	<a href="#">tmin 2.5m</a>	<a href="#">tmin 30s</a>
maximum temperature (°C)	<a href="#">tmax 10m</a>	<a href="#">tmax 5m</a>	<a href="#">tmax 2.5m</a>	<a href="#">tmax 30s</a>
average temperature (°C)	<a href="#">tavg 10m</a>	<a href="#">tavg 5m</a>	<a href="#">tavg 2.5m</a>	<a href="#">tavg 30s</a>
precipitation (mm)	<a href="#">prec 10m</a>	<a href="#">prec 5m</a>	<a href="#">prec 2.5m</a>	<a href="#">prec 30s</a>
solar radiation (kJ m <sup>-2</sup> day <sup>-1</sup> )	<a href="#">srad 10m</a>	<a href="#">srad 5m</a>	<a href="#">srad 2.5m</a>	<a href="#">srad 30s</a>
wind speed (m s <sup>-1</sup> )	<a href="#">wind 10m</a>	<a href="#">wind 5m</a>	<a href="#">wind 2.5m</a>	<a href="#">wind 30s</a>
water vapor pressure (kPa)	<a href="#">vapr 10m</a>	<a href="#">vapr 5m</a>	<a href="#">vapr 2.5m</a>	<a href="#">vapr 30s</a>

- Maximum user-friendly and easy to use
- High spatial resolution data
- Data are available in .geotiff format which is easier to handle in GIS

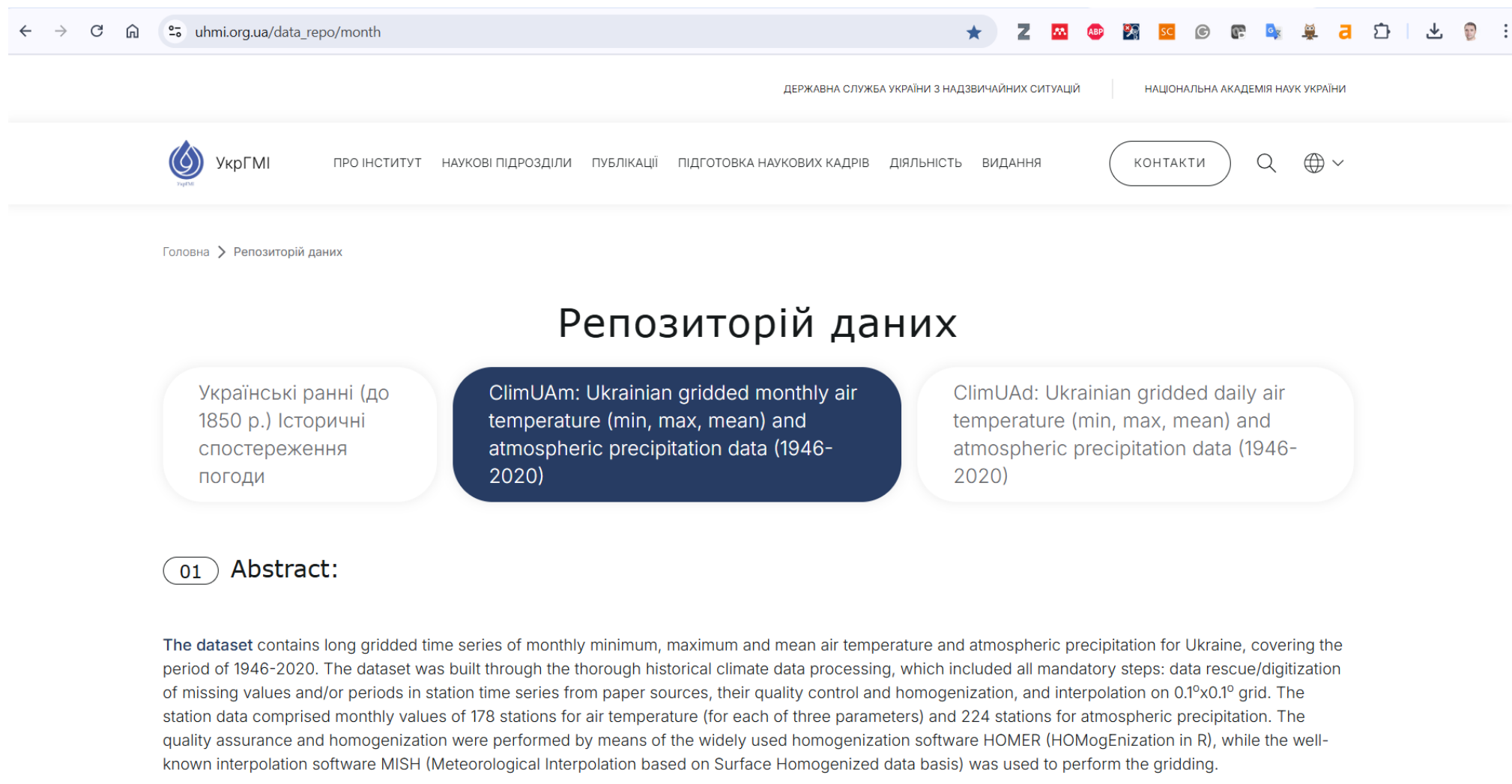


The screenshot shows the WorldClim website's 'Future climate, 10 minutes spatial resolution' page. The page title is 'Future climate, 10 minutes spatial resolution'. Below the title, it states: 'See the [main page](#) for background information and for other spatial resolutions. Downscaled monthly future climate data from CMIP6 is available in GeoTiff files for nine GCMs and four SSPs for the following time periods: 2021-2040, 2041-2060, 2061-2080, and 2081-2100. The climate variables available are tn - monthly average minimum temperature (°C), tx - monthly average maximum temperature (°C), pr - monthly total precipitation (mm), and bc - bioclimatic variables.'

**2021-2040**

GCM	ssp126	ssp245	ssp370	ssp585
ACCESS-CM2	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>
BCC-CSM2-MR	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>
CMCC-ESM2	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>
EC-Earth3-Veg	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>
FIO-ESM-2-0	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>		<a href="#">tn, tx, pr, bc</a>
GFDL-ESM4	<a href="#">tn, tx, pr, bc</a>		<a href="#">tn, tx, pr, bc</a>	<a href="#">pr</a>
GISS-E2-1-G	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>
HadGEM3-GC31-LL	<a href="#">tn, tx, pr, bc</a>	<a href="#">tn, tx, pr, bc</a>		<a href="#">tn, tx, pr, bc</a>

# Portals for downloading raw observation data: UkrHydroMet Insitute



The screenshot shows the website of the UkrHydroMet Institute's data repository. The browser address bar displays 'uhmi.org.ua/data\_repo/month'. The website header includes the Ukrainian State Emergency Service and the National Academy of Sciences logos. The main navigation bar features the UkrHydroMet logo and links to 'ПРО ІНСТИТУТ', 'НАУКОВІ ПІДРОЗДІЛИ', 'ПУБЛІКАЦІЇ', 'ПІДГОТОВКА НАУКОВИХ КАДРІВ', 'ДІЯЛЬНІСТЬ', 'ВИДАННЯ', and 'КОНТАКТИ'. A search icon and a globe icon are also present. The breadcrumb trail shows 'Головна > Репозиторій даних'. The main heading is 'Репозиторій даних'. Below it, three data repository cards are displayed: 'Українські ранні (до 1850 р.) Історичні спостереження погоди', 'ClimUAm: Ukrainian gridded monthly air temperature (min, max, mean) and atmospheric precipitation data (1946-2020)', and 'ClimUAd: Ukrainian gridded daily air temperature (min, max, mean) and atmospheric precipitation data (1946-2020)'. The 'Abstract:' section is marked with a '01' icon. The abstract text describes the dataset's content, processing steps, and the software used for homogenization and interpolation.

uhmi.org.ua/data\_repo/month

ДЕРЖАВНА СЛУЖБА УКРАЇНИ З НАДЗВИЧАЙНИХ СИТУАЦІЙ | НАЦІОНАЛЬНА АКАДЕМІЯ НАУК УКРАЇНИ

УкрГМІ | ПРО ІНСТИТУТ | НАУКОВІ ПІДРОЗДІЛИ | ПУБЛІКАЦІЇ | ПІДГОТОВКА НАУКОВИХ КАДРІВ | ДІЯЛЬНІСТЬ | ВИДАННЯ | КОНТАКТИ

Головна > Репозиторій даних

## Репозиторій даних

- Українські ранні (до 1850 р.) Історичні спостереження погоди
- ClimUAm: Ukrainian gridded monthly air temperature (min, max, mean) and atmospheric precipitation data (1946-2020)
- ClimUAd: Ukrainian gridded daily air temperature (min, max, mean) and atmospheric precipitation data (1946-2020)

01 Abstract:

**The dataset** contains long gridded time series of monthly minimum, maximum and mean air temperature and atmospheric precipitation for Ukraine, covering the period of 1946-2020. The dataset was built through the thorough historical climate data processing, which included all mandatory steps: data rescue/digitization of missing values and/or periods in station time series from paper sources, their quality control and homogenization, and interpolation on 0.1°x0.1° grid. The station data comprised monthly values of 178 stations for air temperature (for each of three parameters) and 224 stations for atmospheric precipitation. The quality assurance and homogenization were performed by means of the widely used homogenization software HOMER (HOMogEnization in R), while the well-known interpolation software MISH (Meteorological Interpolation based on Surface Homogenized data basis) was used to perform the gridding.

# Portals for downloading raw observation data: NOAA

The screenshot shows the NOAA Climate Data Online (CDO) website. The browser address bar displays `ncei.noaa.gov/cdo-web/`. The NOAA logo and the text "NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION" and "NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION" are at the top. A navigation bar includes links for Home, Climate Information, Data Access, Contact, and About, along with a search bar. Below the navigation bar, a breadcrumb trail shows "Home > Climate Data Online" and a list of tools: Datasets, Search Tool, Mapping Tool, Data Tools, and Help. The main content area is titled "Climate Data Online" and includes a description of the service: "Climate Data Online (CDO) provides free access to NCDC's archive of global historical weather and climate data in addition to station history information. These data include quality controlled daily, monthly, seasonal, and yearly measurements of temperature, precipitation, wind, and degree days as well as radar data and 30-year Climate Normals. Customers can also order most of these data as [certified hard copies](#) for legal use." To the right of the text is a graphic of a landscape with a sun, clouds, and a lightning bolt. Below the text are four icons with corresponding links and descriptions: "Browse Datasets" (Browse documentation, samples, and links), "Certify Orders" (Get orders certified for legal use (requires payment)), "Check Status" (Check the status of an order that has been placed), and "Find Help" (Find answers to questions about data and ordering). At the bottom, a section titled "DISCOVER DATA BY" features three buttons: "SEARCH TOOL", "MAPPING TOOL", and "DATA TOOLS".

ncei.noaa.gov/cdo-web/

NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION  
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Home Climate Information Data Access Contact About

Search

Home > Climate Data Online

Datasets Search Tool Mapping Tool Data Tools Help

## Climate Data Online

Climate Data Online (CDO) provides free access to NCDC's archive of global historical weather and climate data in addition to station history information. These data include quality controlled daily, monthly, seasonal, and yearly measurements of temperature, precipitation, wind, and degree days as well as radar data and 30-year Climate Normals. Customers can also order most of these data as [certified hard copies](#) for legal use.

[Browse Datasets](#)  
Browse documentation, samples, and links

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Get orders certified for legal use (requires payment)

[Check Status](#)  
Check the status of an order that has been placed

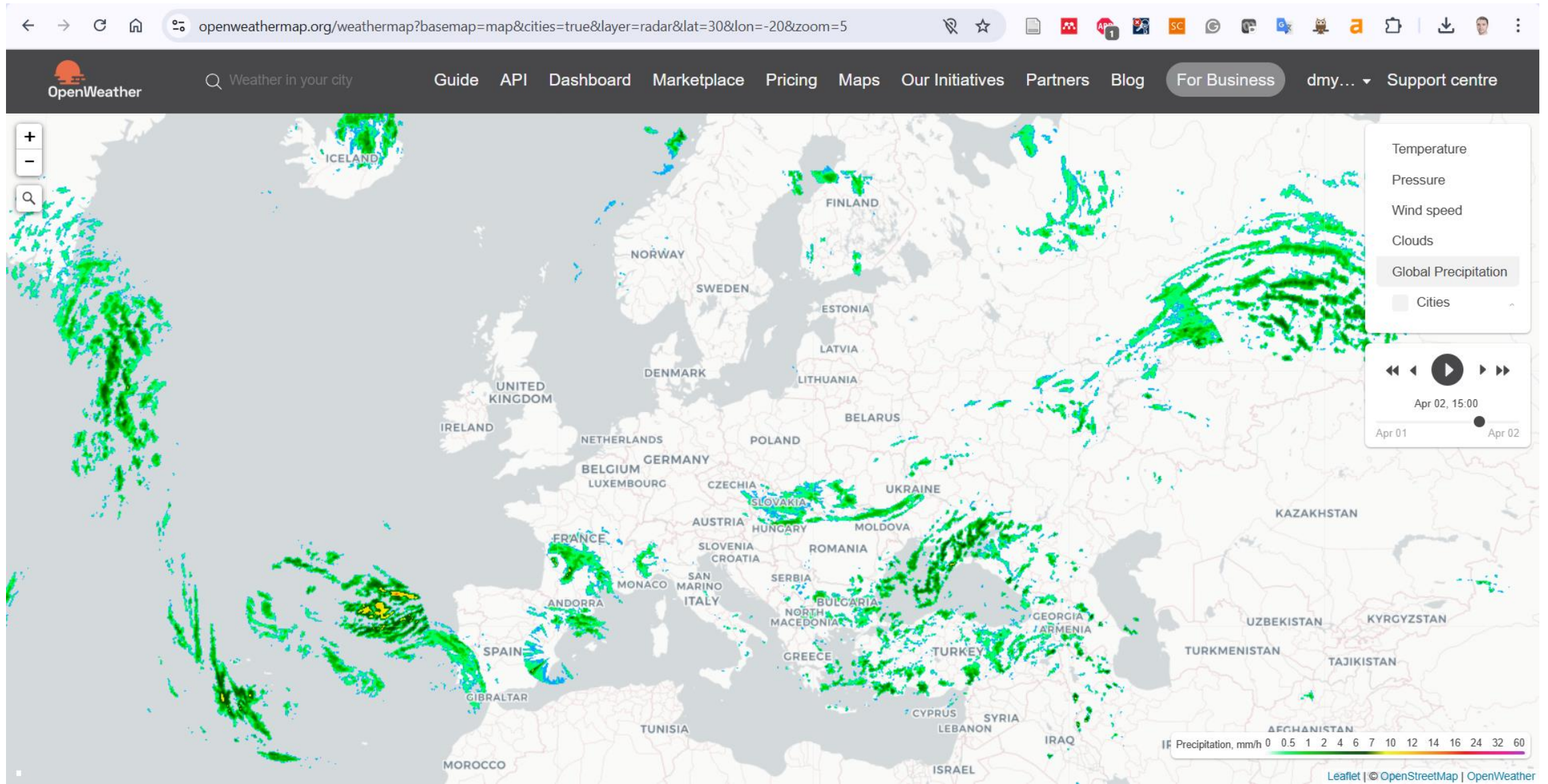
[Find Help](#)  
Find answers to questions about data and ordering

DISCOVER DATA BY

SEARCH TOOL MAPPING TOOL DATA TOOLS



# API services for retrieving climate data online: OpenWeatherMap

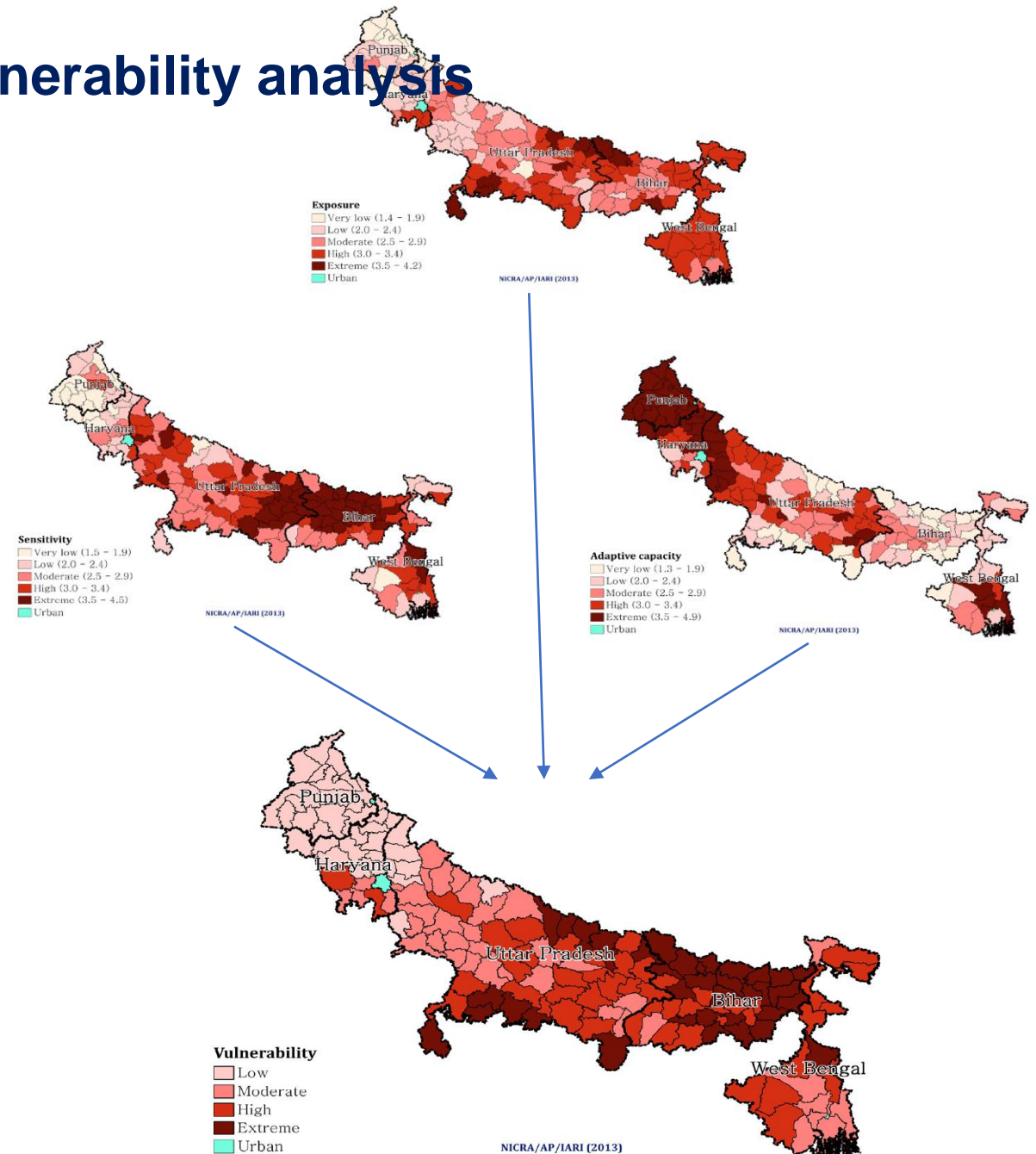
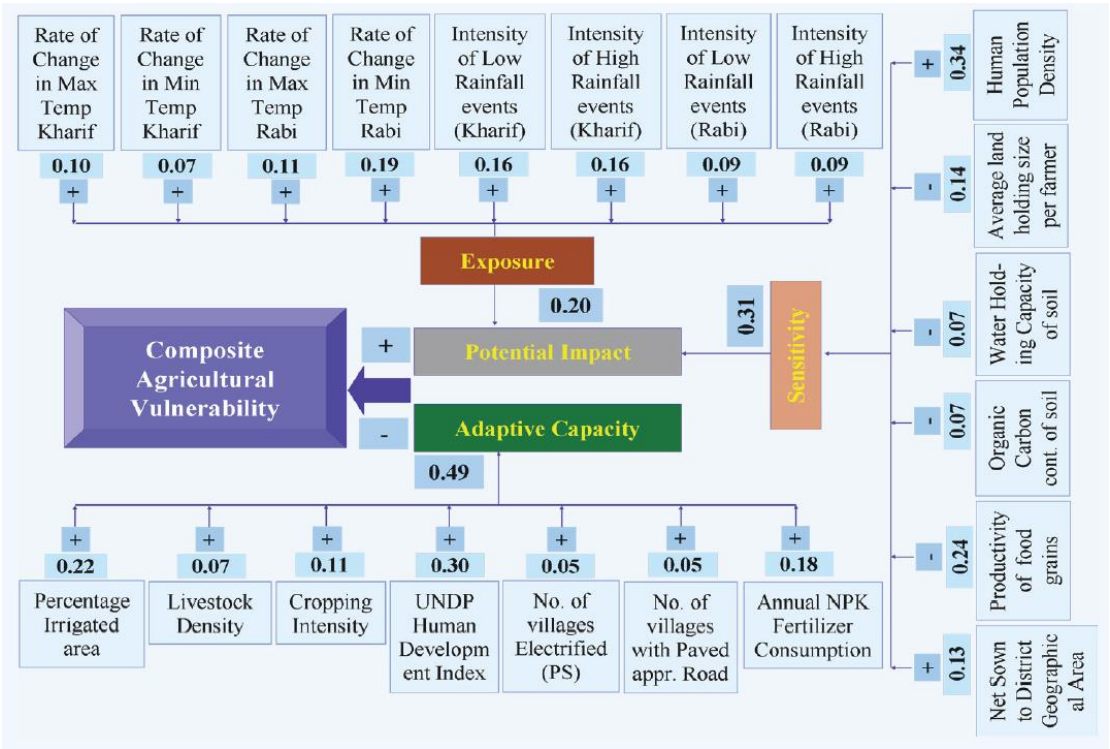


## Practical usefulness of GIS application in climate services



- Understanding of spatial distribution and variability of climate indicators in a particular location
- Effective visualisation of climate change evidence, effects and consequences
- Identification of risk and vulnerability to climate change through geospatial analysis (overlay and proximity analysis, elevation and hydrologic modelling, etc)
- Selection and substantiation of relevant adaptation and mitigation measures

# GIS application in climate risk and vulnerability analysis



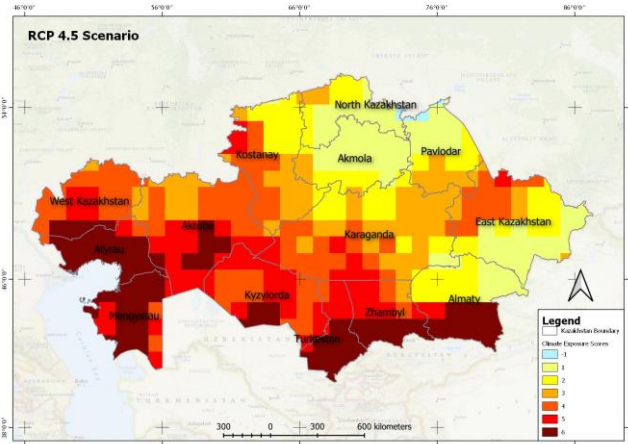
Sehgal V. et al. Vulnerability of Agriculture to Climate Change: District Level Assessment in the Indo-Gangetic Plains, IARI. 2013



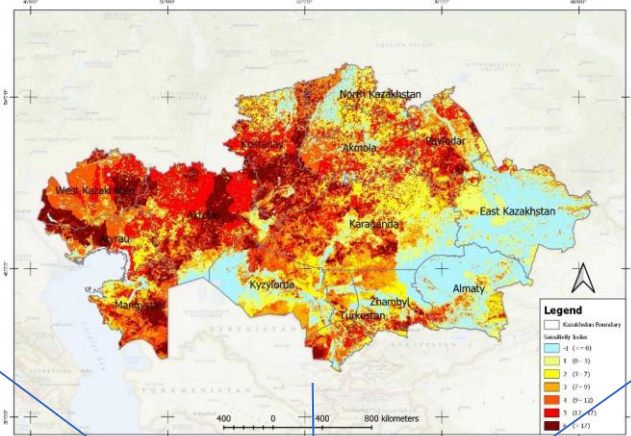
# GIS application in climate risk and vulnerability analysis



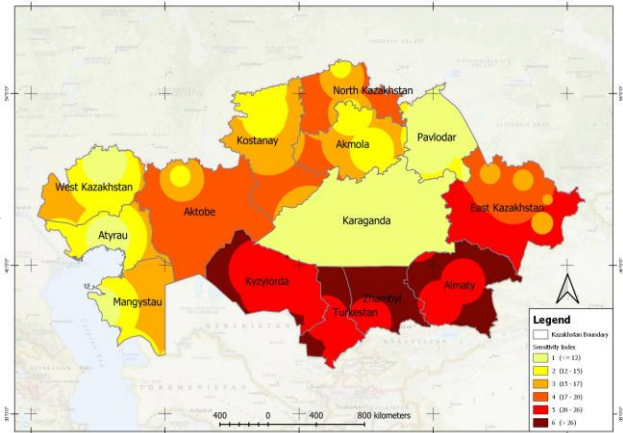
Total exposure



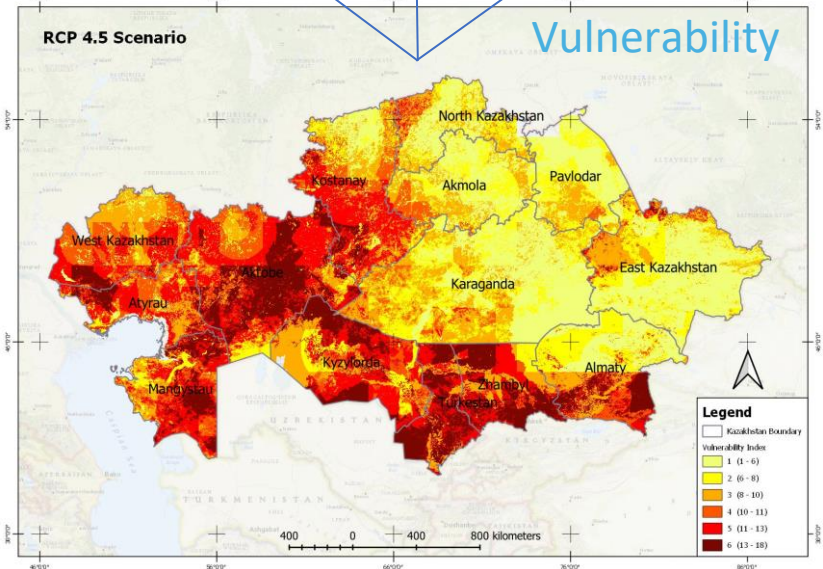
Geographic sensitivity



Socio economic sensitivity



Vulnerability

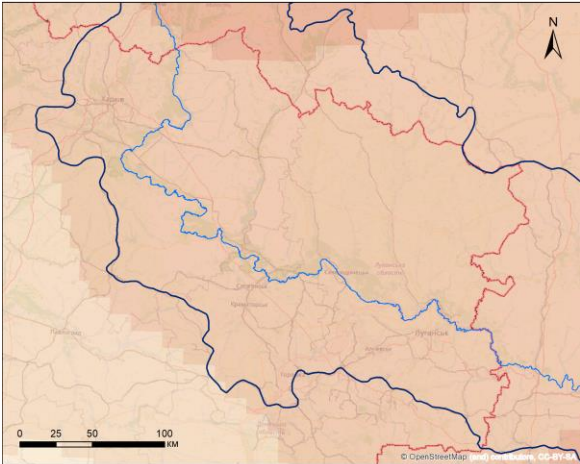


Climate Change Adaptation in Kazakhstan,  
Climate Adaptation and Mitigation Program  
for the Aral Sea Basin (CAMP4ASB), 2021

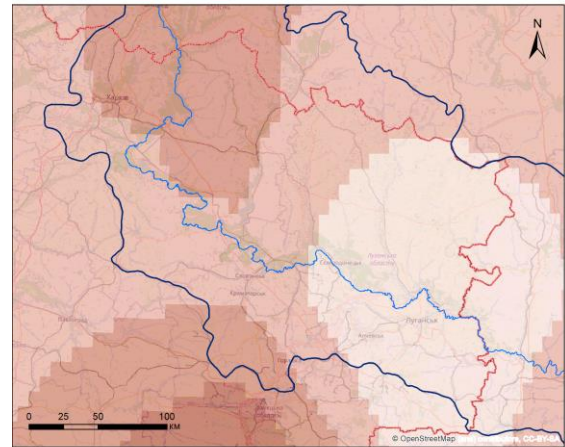


# GIS application in assessment of climate change in river basin

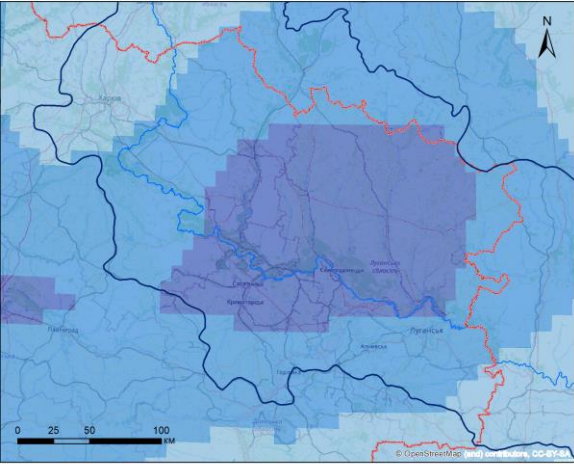
Зміна максимальної температури - RCP 4.5



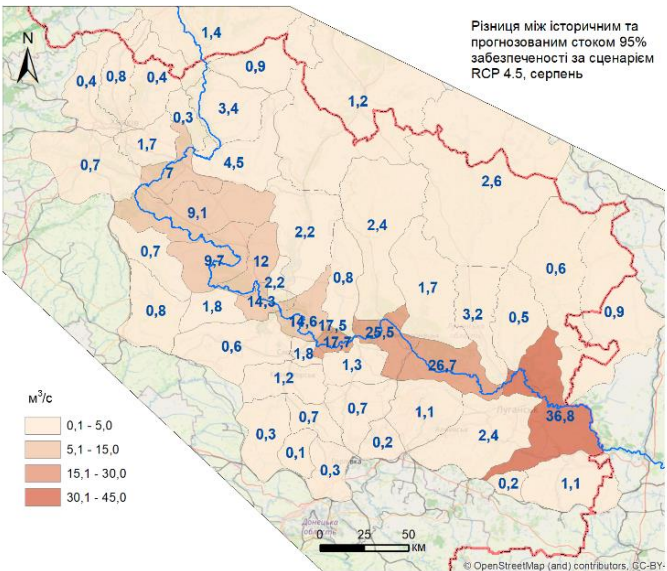
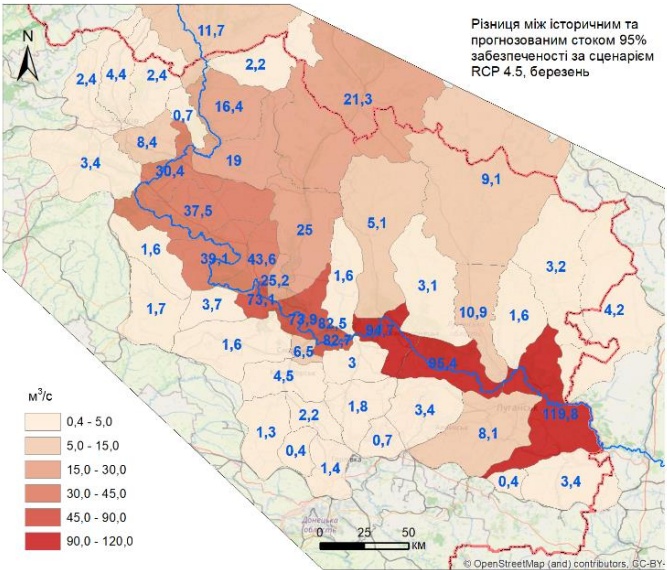
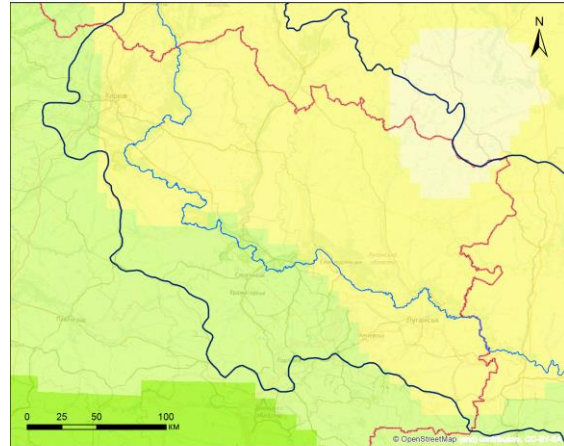
Зміна тривалості посухи - RCP 4.5



Зміна суми опадів - RCP 4.5



Зміна тривалості періоду вегетації - RCP 4.5



Climate Change in Siv.  
Donets River basin:  
UNICEF project, 2021