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STECCI Climate Change Modelling for Medieval Limestone Heritage

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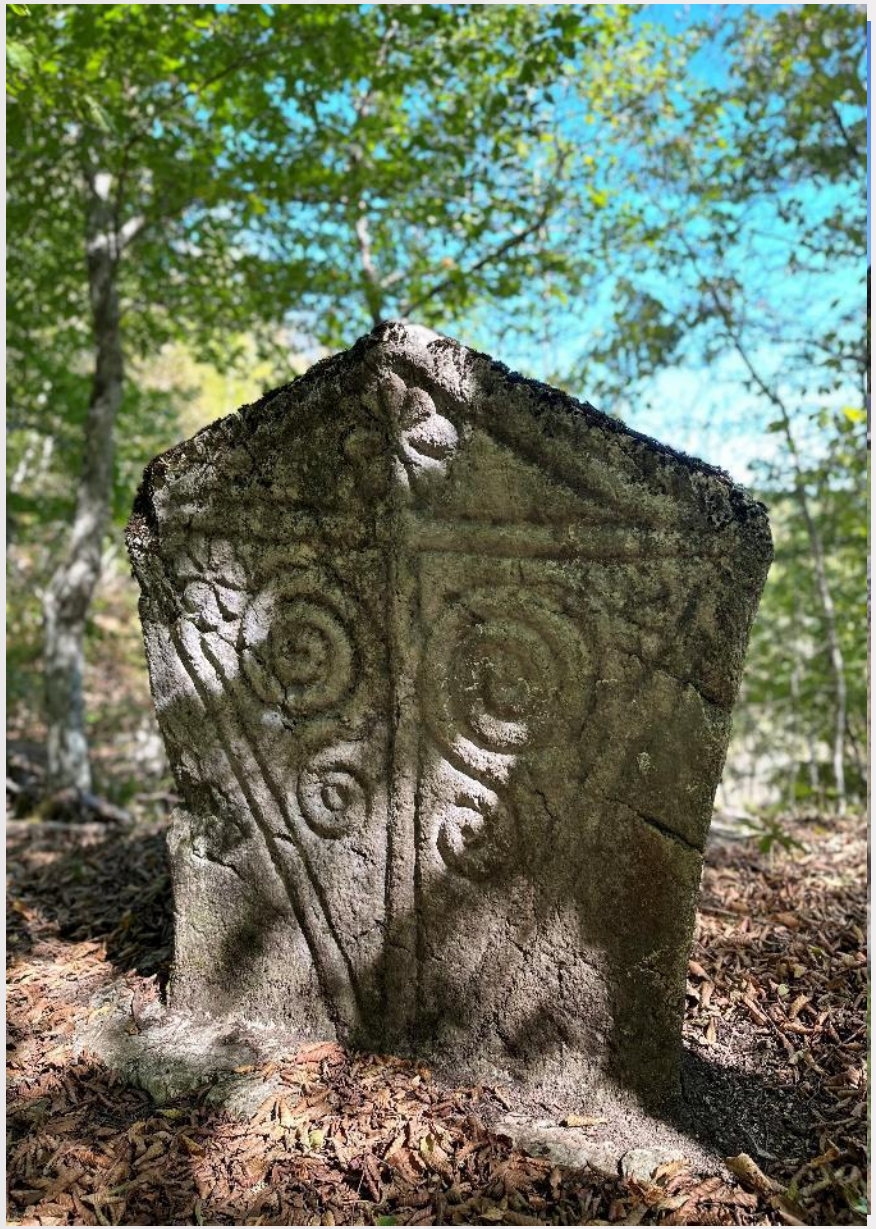
STECCI

EGU26
GENERAL ASSEMBLY



Stećci, BiH

STECCI and Stećci

STECCI is a multidisciplinary Horizon Europe R&I project combining expert knowledge and skills from conservation and conservation science, climate and environmental sciences, life sciences, social sciences, economy, creative industries and humanities to overcome the challenges in the **Cultural Heritage** realm imposed by **Climate Change** .

Stećci are medieval monolithic tombstones found primarily in **Bosnia and Herzegovina**, but also in parts of **Croatia**, **Montenegro** and **Serbia**, most classified as UNESCO World Heritage Sites. These unique tombstones were mainly produced from the **12th to the 16th century**.

STECCI sites

Križevići, B&H

Kopošići, B&H

Žabljak, MNE

Sarajevo, B&H

Radimlja, B&H

Ravanjska vrata, B&H

Split, HR

Hundskirche, AT

Kleinbardorf, DE

Perućac, SRB

Cista Velika, HR

Dugo polje, B&H

Mdina Rabat, MT

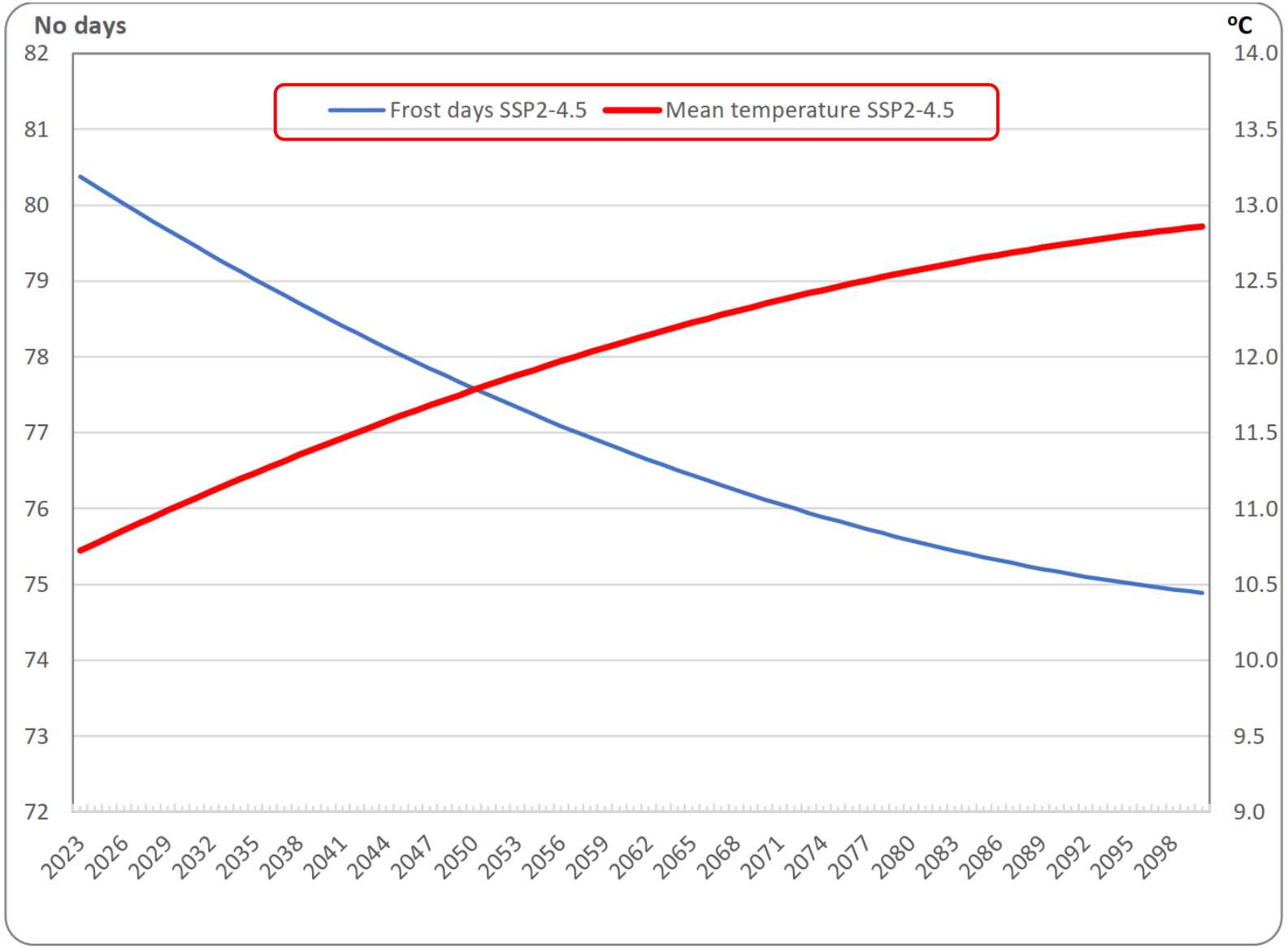
Unsleben, DE

Caen, FR

Synthesis of projected climate change for the STECCI project sites region

Region: Mediterranean			
Scenario SSP2-4.5	Near Term (2021-2040)	Medium Term (2041-2060)	Long Term (2081-2100)
Mean temperature (T) Change deg C	0,8	1,4	2,2
Total precipitation (PR) Change %	-1,7	-5	-7,7
Maximum 1-day precipitation (RX1day) Change %	2,3	2,2	3,9
Frost days (FD) Change days	-2,5	-3,6	-5,8
Scenario SSP5-8.5			
Mean temperature (T) Change deg C	1	2,1	4,6
Total precipitation (PR) Change %	-2,7	-8,2	-19,2
Maximum 1-day precipitation (RX1day) Change %	1,8	3,4	4,9
Frost days (FD) Change days	-2,9	-4,5	-10,2
Region: Western and Central Europe			
Scenario SSP2-4.5	Near Term (2021-2040)	Medium Term (2041-2060)	Long Term (2081-2100)
Mean temperature (T) Change deg C	1	1,6	2,4
Total precipitation (PR) Change %	1,8	0,6	1,7
Maximum 1-day precipitation (RX1day) Change %	4	6	9,9
Frost days (FD) Change days	-11	-15,7	-24,3
Scenario SSP5-8.5			
Mean temperature (T) Change deg C	1,2	2,3	5,1
Total precipitation (PR) Change %	0,6	1,1	0,5
Maximum 1-day precipitation (RX1day) Change %	3,9	7	16,1
Frost days (FD) Change days	-9,3	-20,9	-47,8

CLIMATE SCENARIO SSP2-4.5 - Sarajevo site

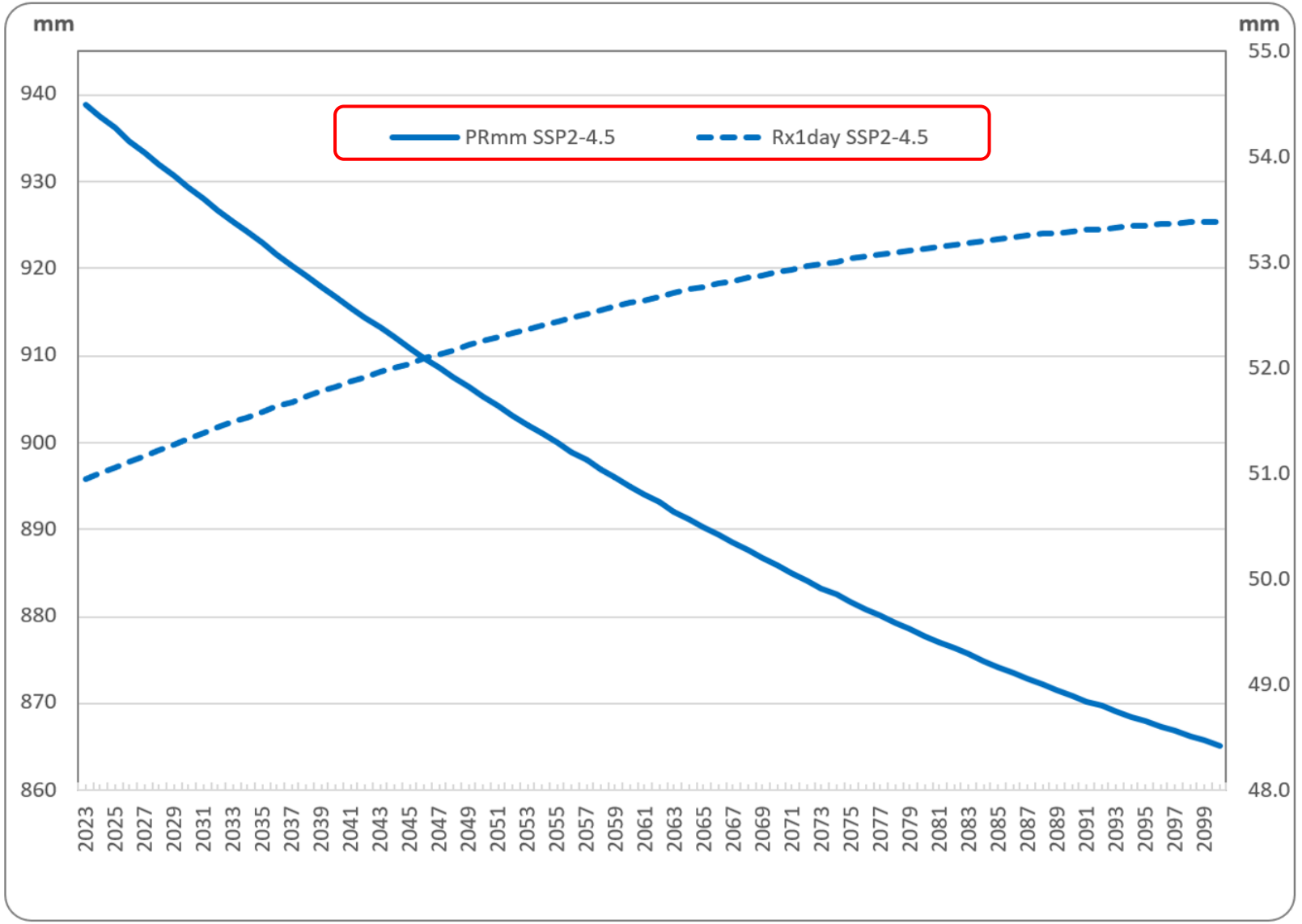


Scenario SSP2-4.5	Near Term (2021-2040)
Mean temperature (T) Change °C	11.4
Frost days (FD) Change days	78.5

Medium Term (2041-2060)	Long Term (2081-2100)
12.1	12.9
76.8	74.9

Mean temperature and frost days for Sarajevo for the period 2022-2100 according to climate scenario SSP2-4.5

CLIMATE SCENARIO SSP2-4.5 - Sarajevo site

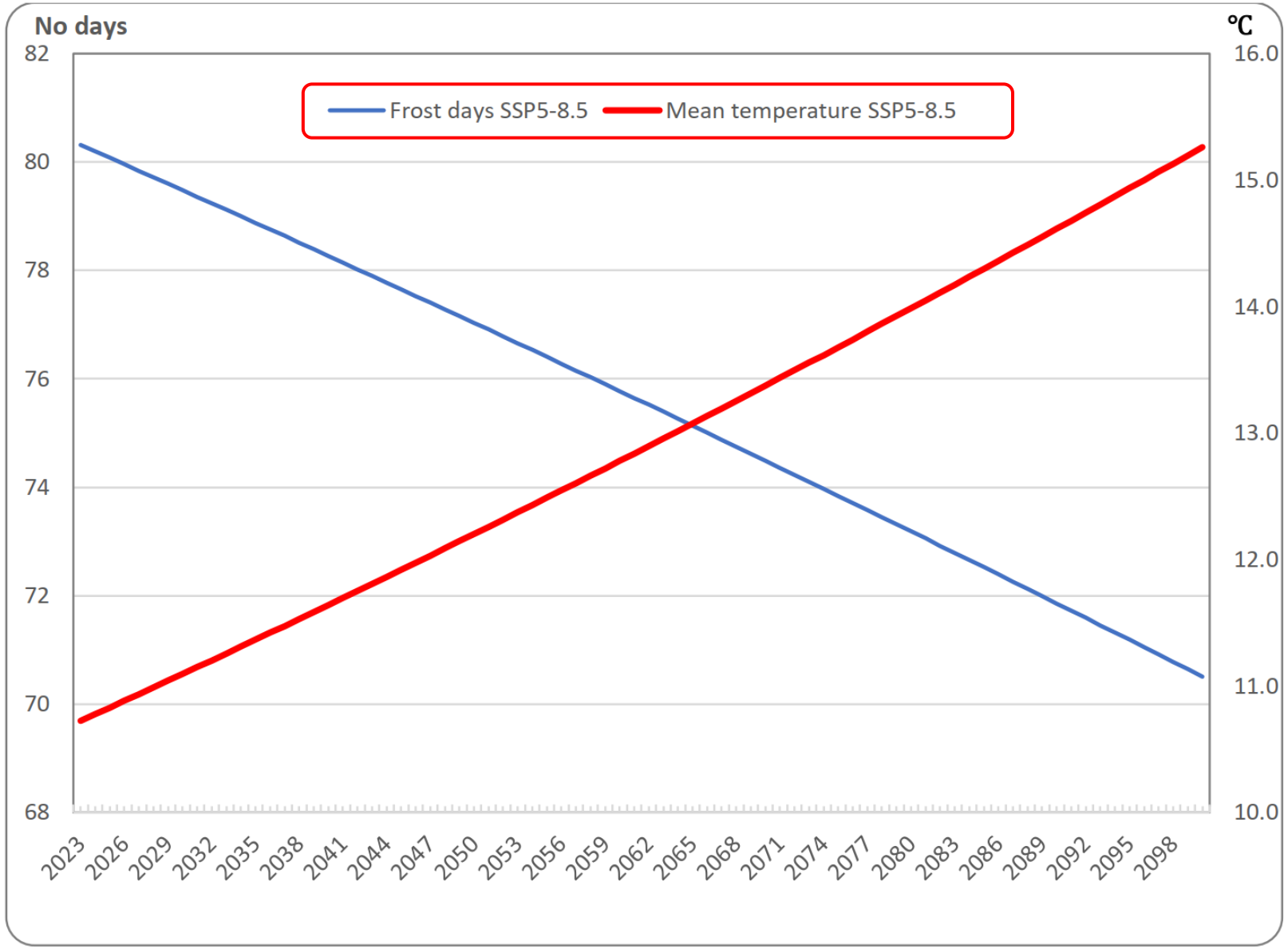


Scenario SSP2-4.5	Near Term (2021-2040)
Total precipitation (PR) Change %	916.7
Maximum 1-day precipitation (RX1day) Change %	51.7

Medium Term (2041-2060)	Long Term (2081-2100)
895.0	865.2
52.3	52.8

Total precipitation and Maximum 1-day precipitation for Sarajevo for the period between 2022-2100 according to climate scenario SSP2-4.5

CLIMATE SCENARIO SSP5-8.5 - Sarajevo site

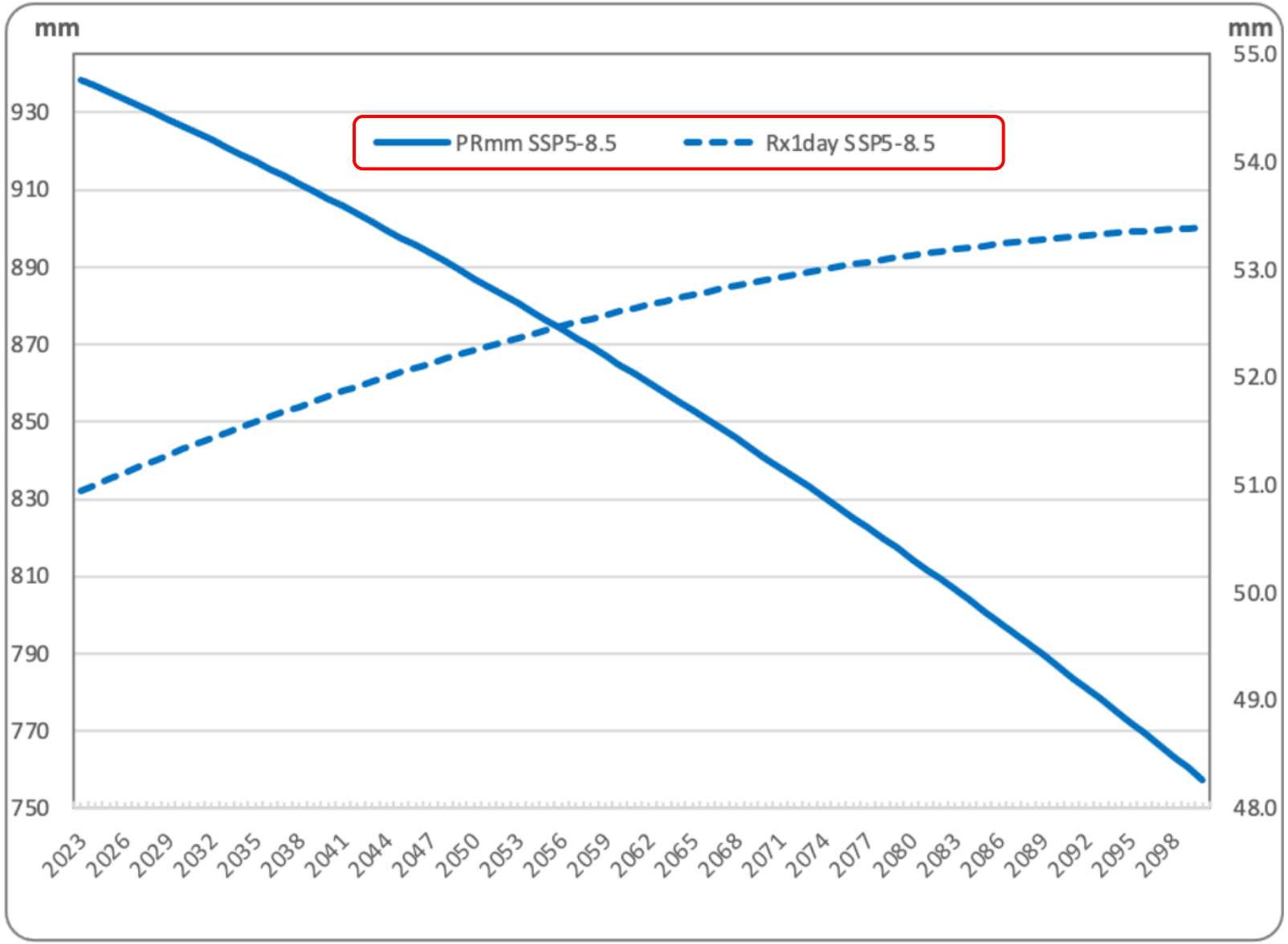


Scenario SSP5-8.5	Near Term (2021-2040)
Mean temperature (T) Change deg C	11.6
Frost days (FD) Change days	78.3

Medium Term (2041-2060)	Long Term (2081-2100)
12.8	15.3
75.8	70.5

Mean temperature and frost days for Sarajevo for the period between 2022-2100 according to climate scenario SSP5-8.5

CLIMATE SCENARIO SSP5-8.5 - Sarajevo site



Scenario SSP5-8.5	Near Term (2021-2040)
Total precipitation (PR) Change %	907.7
Maximum 1-day precipitation (RX1day) Change %	51.8

Medium Term (2041-2060)	Long Term (2081-2100)
864.8	757.4
52.6	53.4

Total precipitation and Maximum 1-day precipitation for the Sarajevo site for the period between 2022-2100 according to climate scenario SSP5-8.5

CLIMATE MODELLING

GIS climate modelling includes **three groups** of climatic layers presented in grid format.

I The first group of climatic grid layers

The first group of GIS climatic layers includes the basic set of climate maps for the recent climatic period.

This group includes the following climatic parameters:

1. Solar radiation

This includes the spatial distribution of total energy radiation, presented as average annual and average monthly values.

2. Sunshine duration

This includes average annual and average monthly sunshine duration, expressed in hours.

3. Air temperature

This includes the following parameters:

a. average annual and monthly air temperature;

a. average annual and monthly maximum air temperature;
b. average annual and monthly minimum air temperature.

4. Precipitation

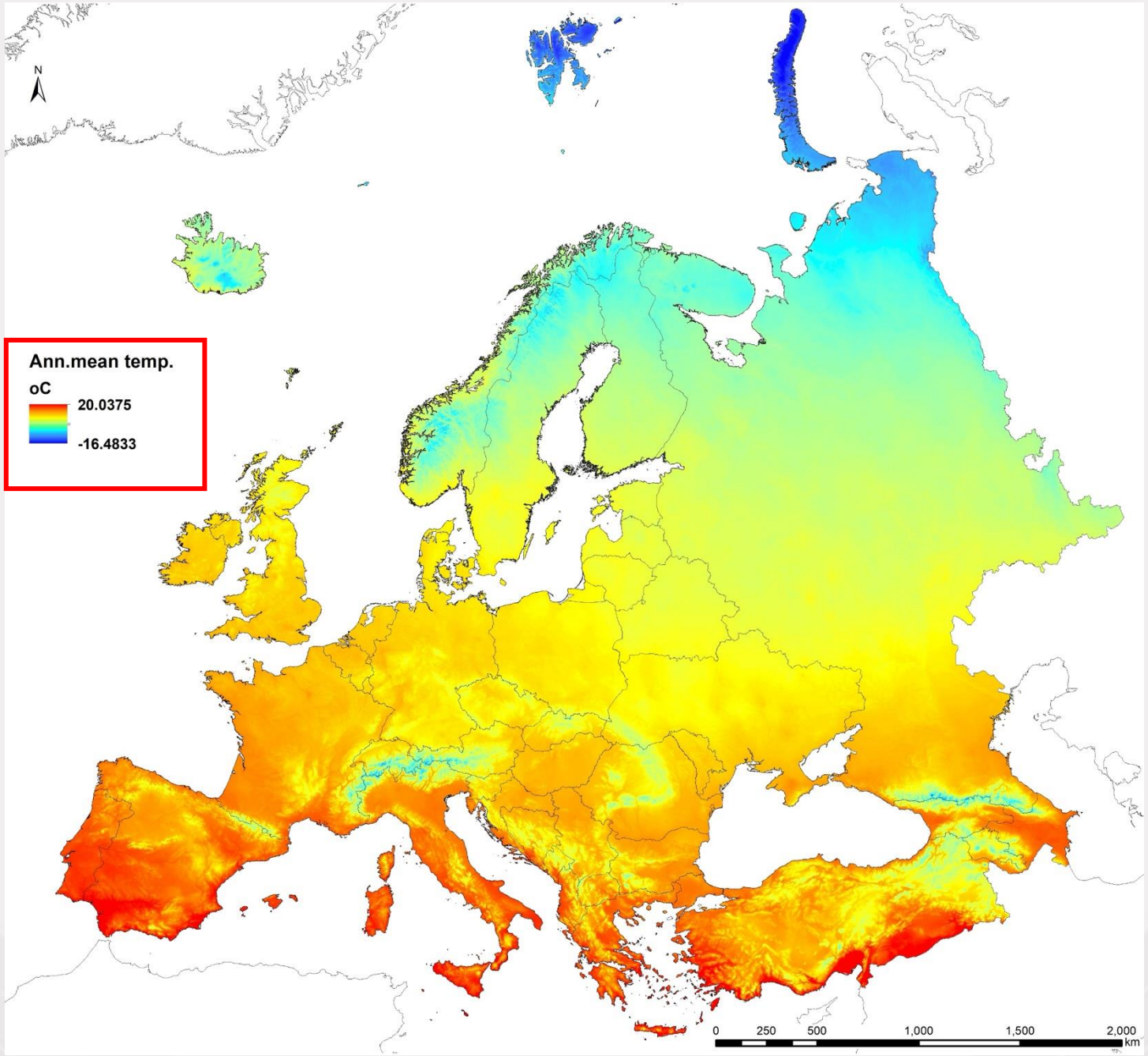
This includes the following parameters:

a. annual and monthly total precipitation;
b. total precipitation of the wettest quarter;
c. total precipitation of the driest quarter;
d. total precipitation of the warmest quarter;
e. total precipitation of the coldest quarter.

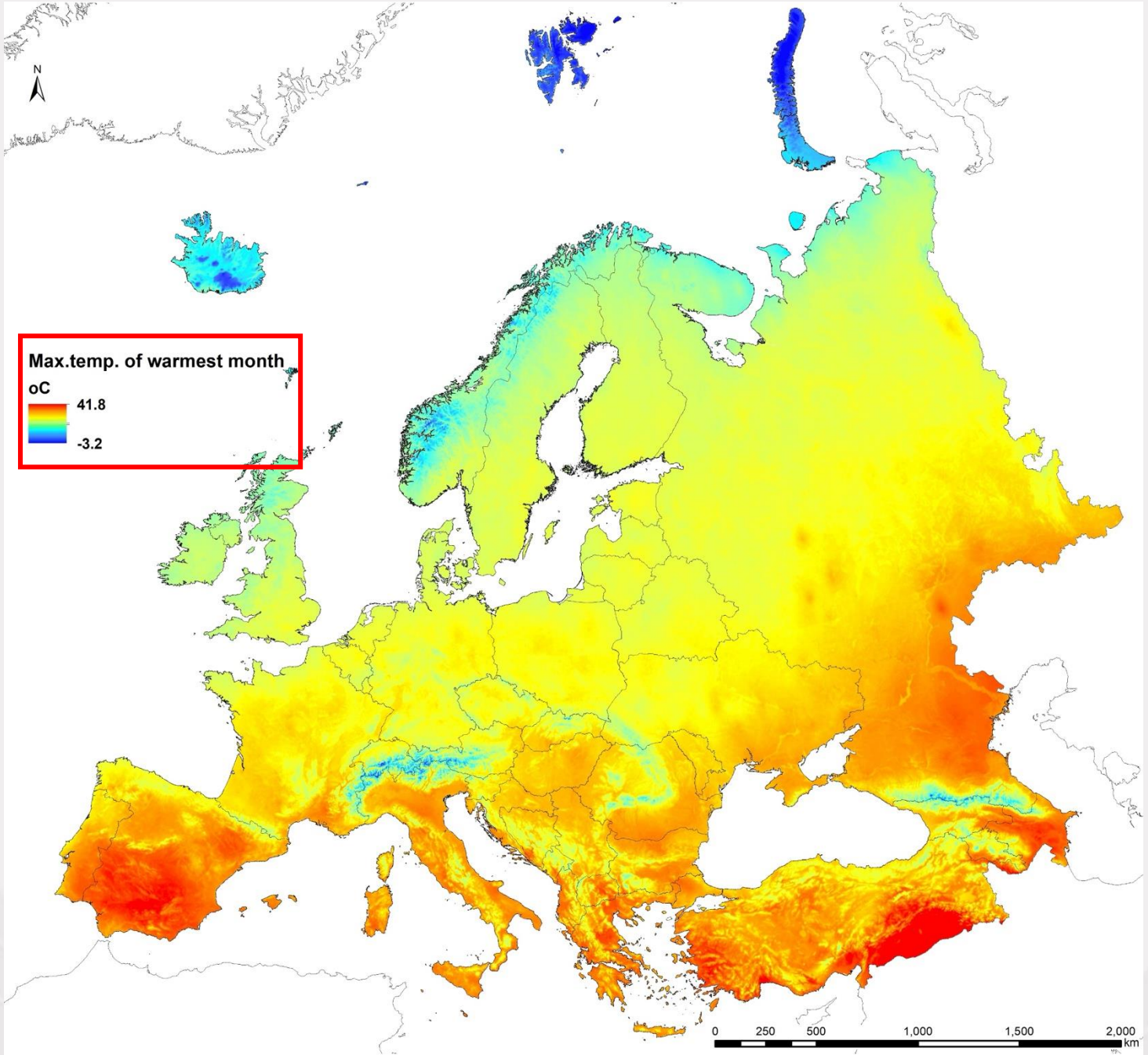
The term **monthly** means that the analysed climatological parameter is presented separately for each of the 12 months of the year.

What is especially important here is the **high spatial resolution**, which allows a much more precise spatial assessment of climatic conditions. This is crucial for heritage sites that are often sensitive to very local environmental differences.

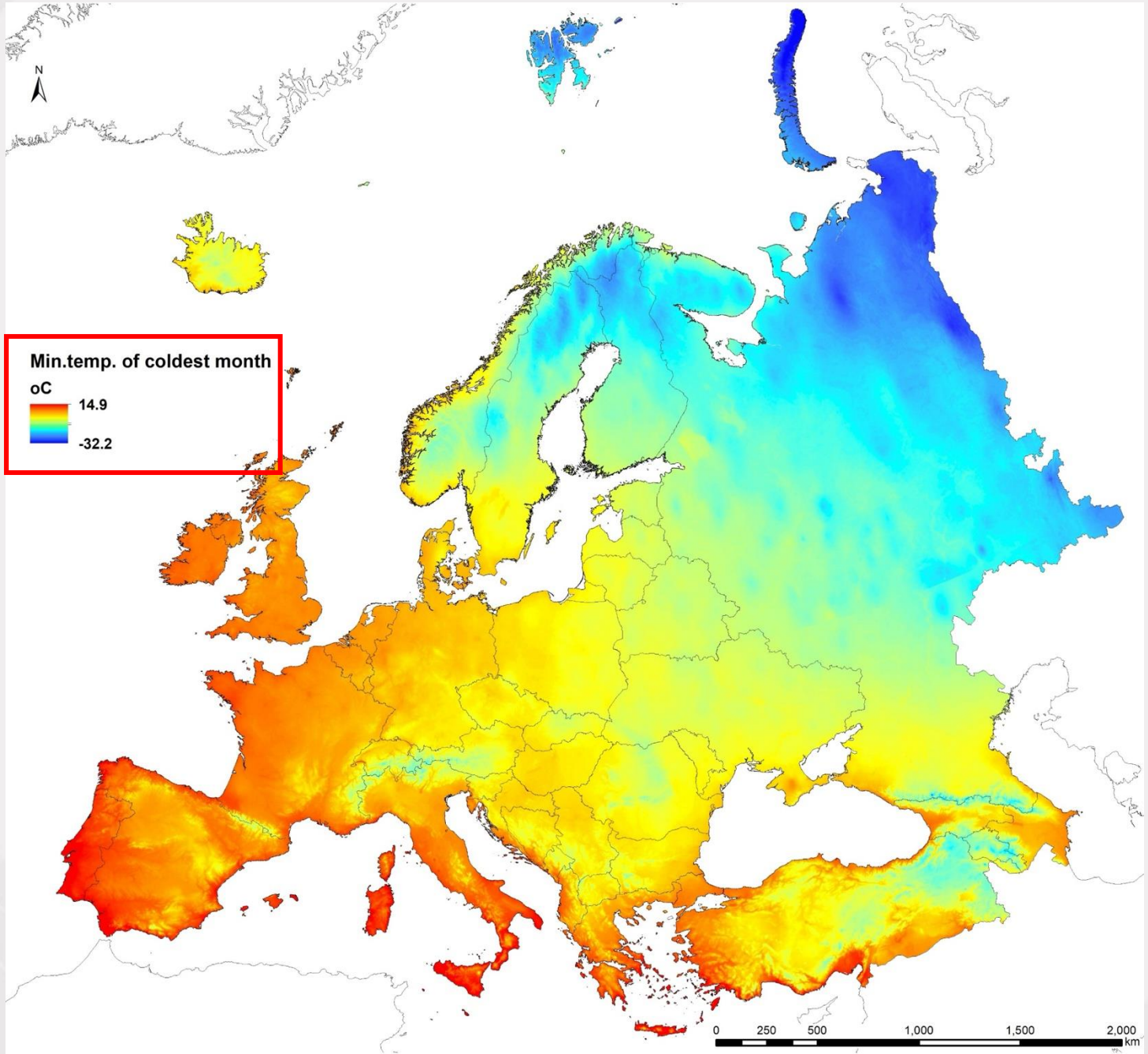
Europe, Average annual air temperature. Recent period.



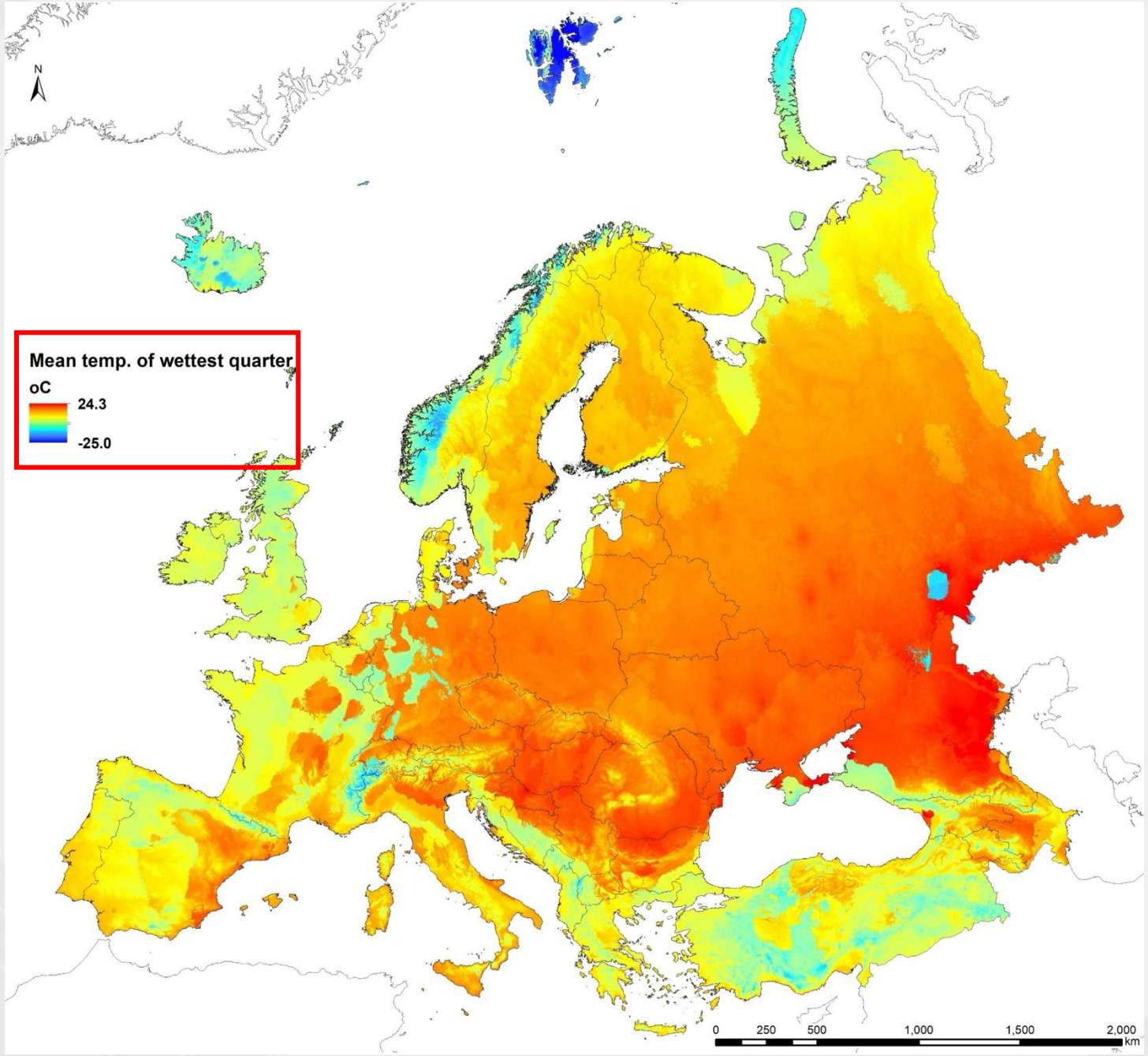
Europe, Max. air temperature of warmest month. Recent period



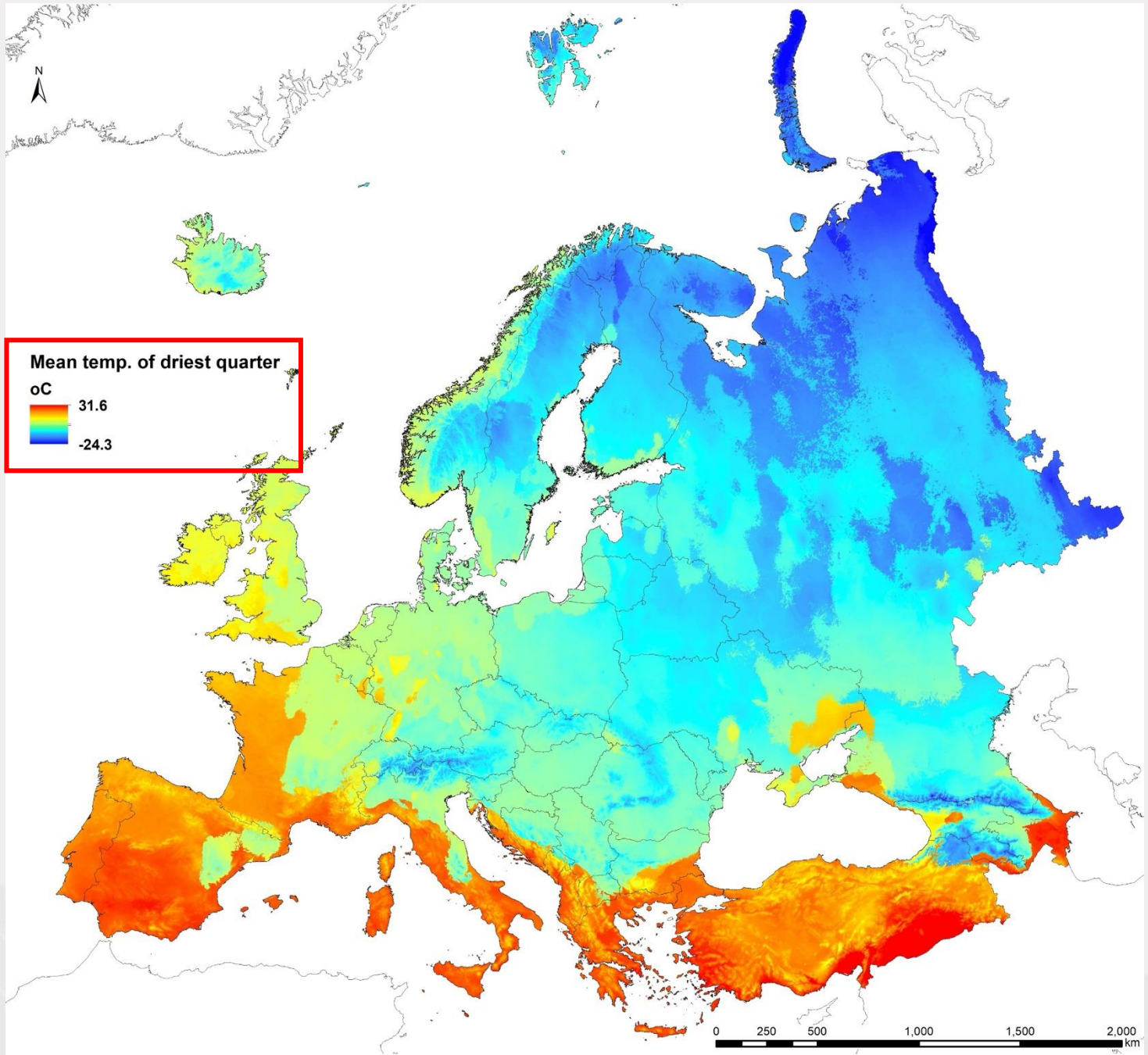
Europe, Min. air temperature of coldest month. Recent period.



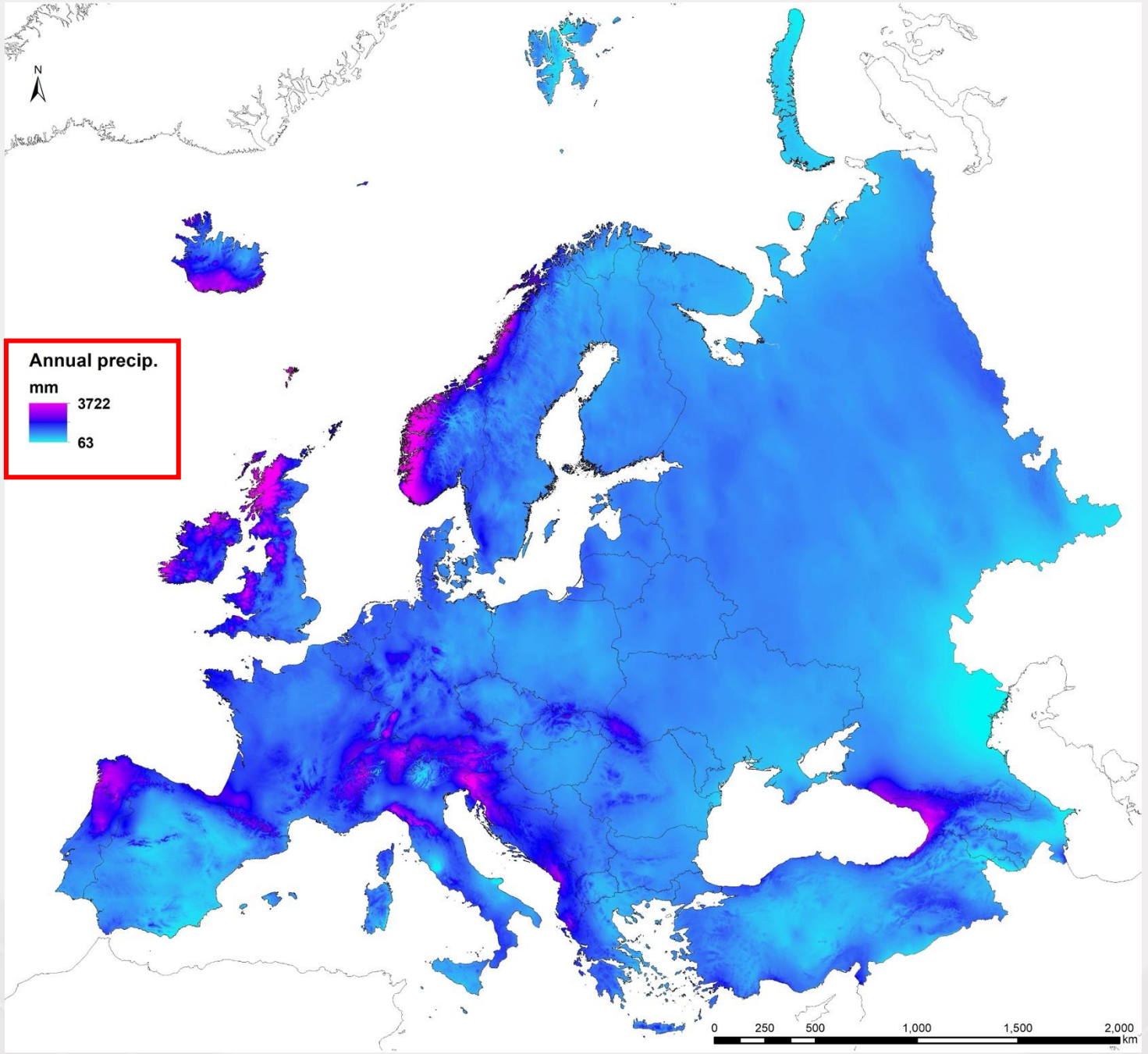
Europe, Mean air temperature of wettest quarter. Recent period.



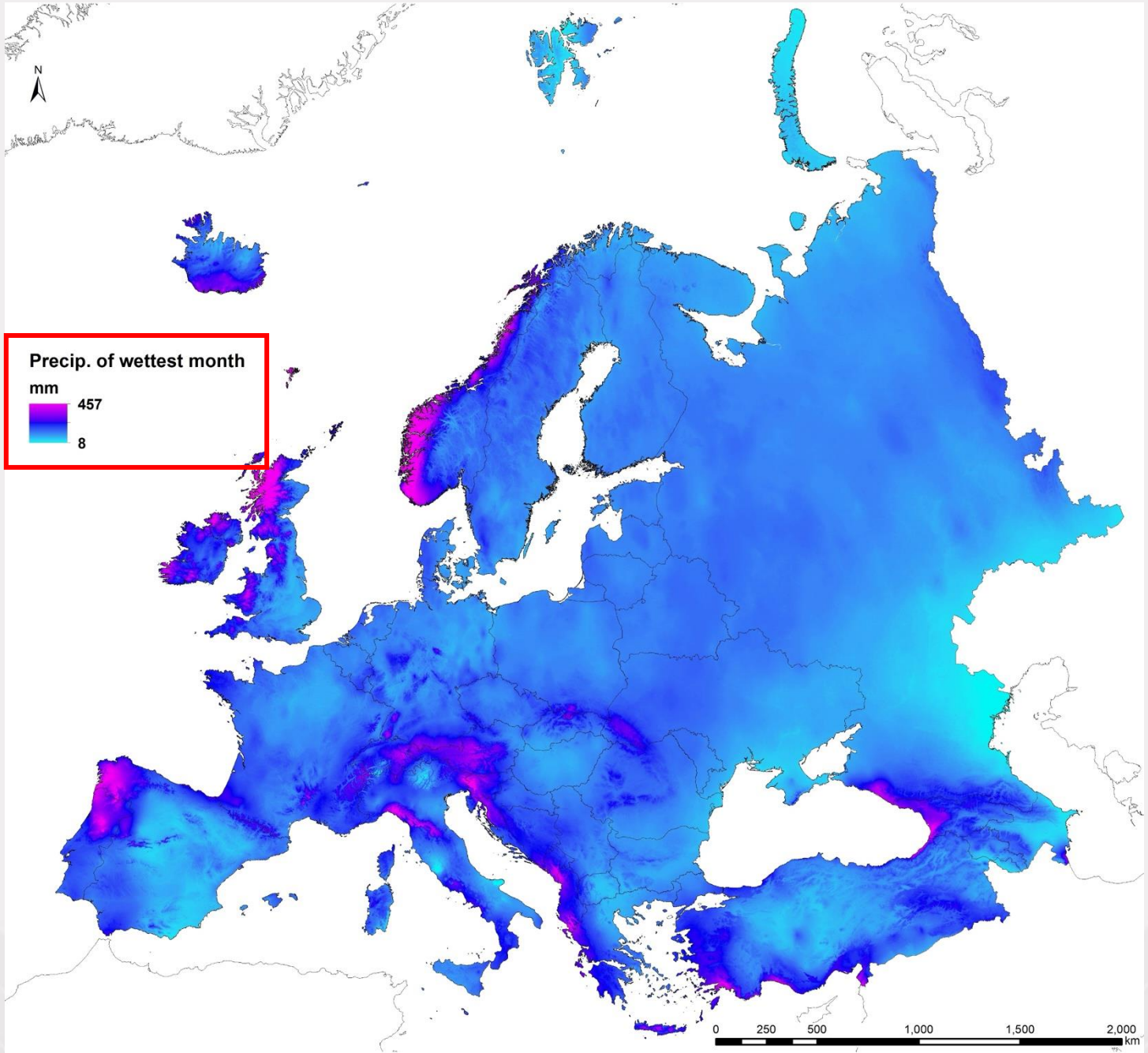
Europe, Mean air temperature of driest quarter. Recent period.



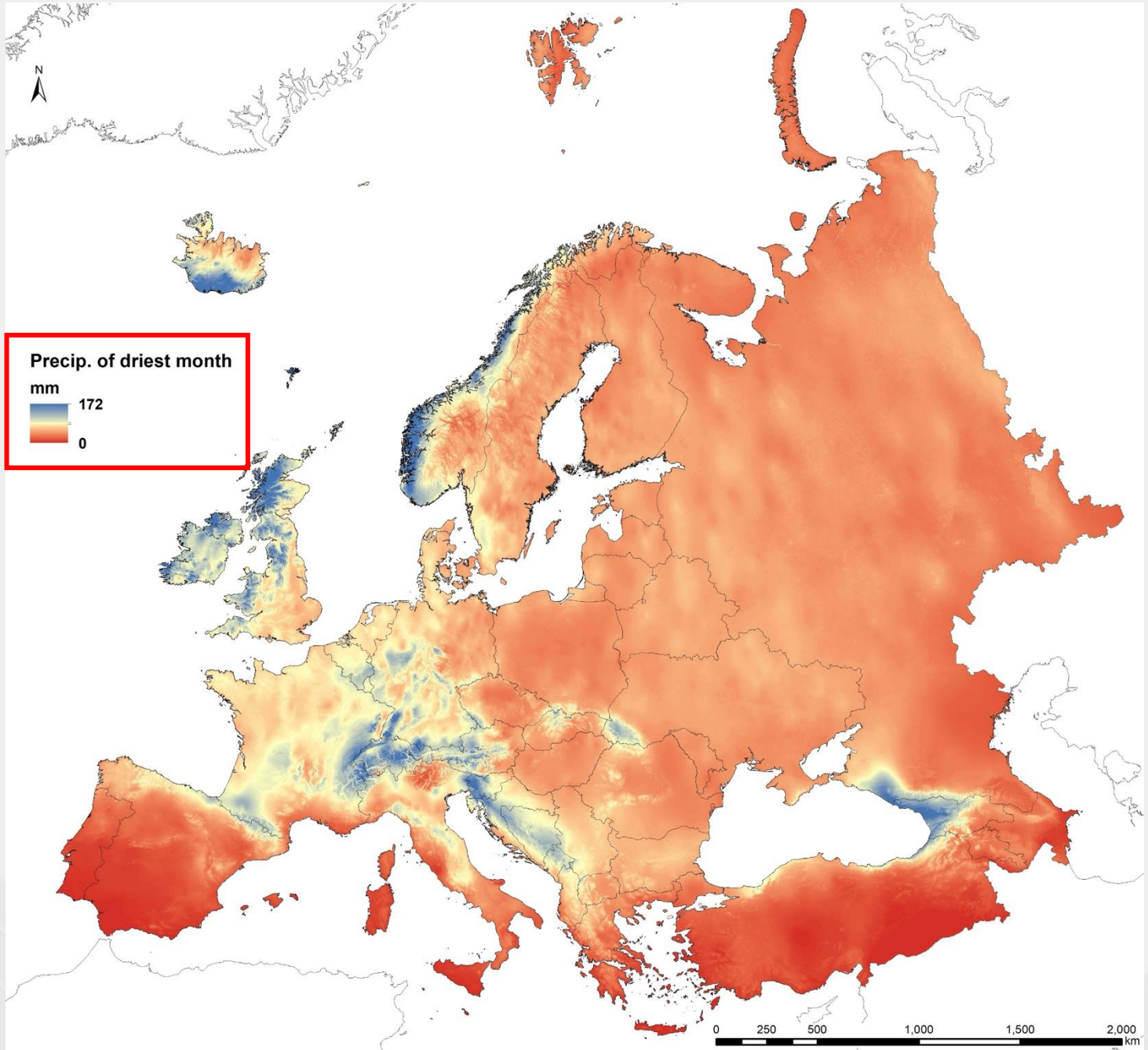
Europe, Annual precipitation. Recent period.



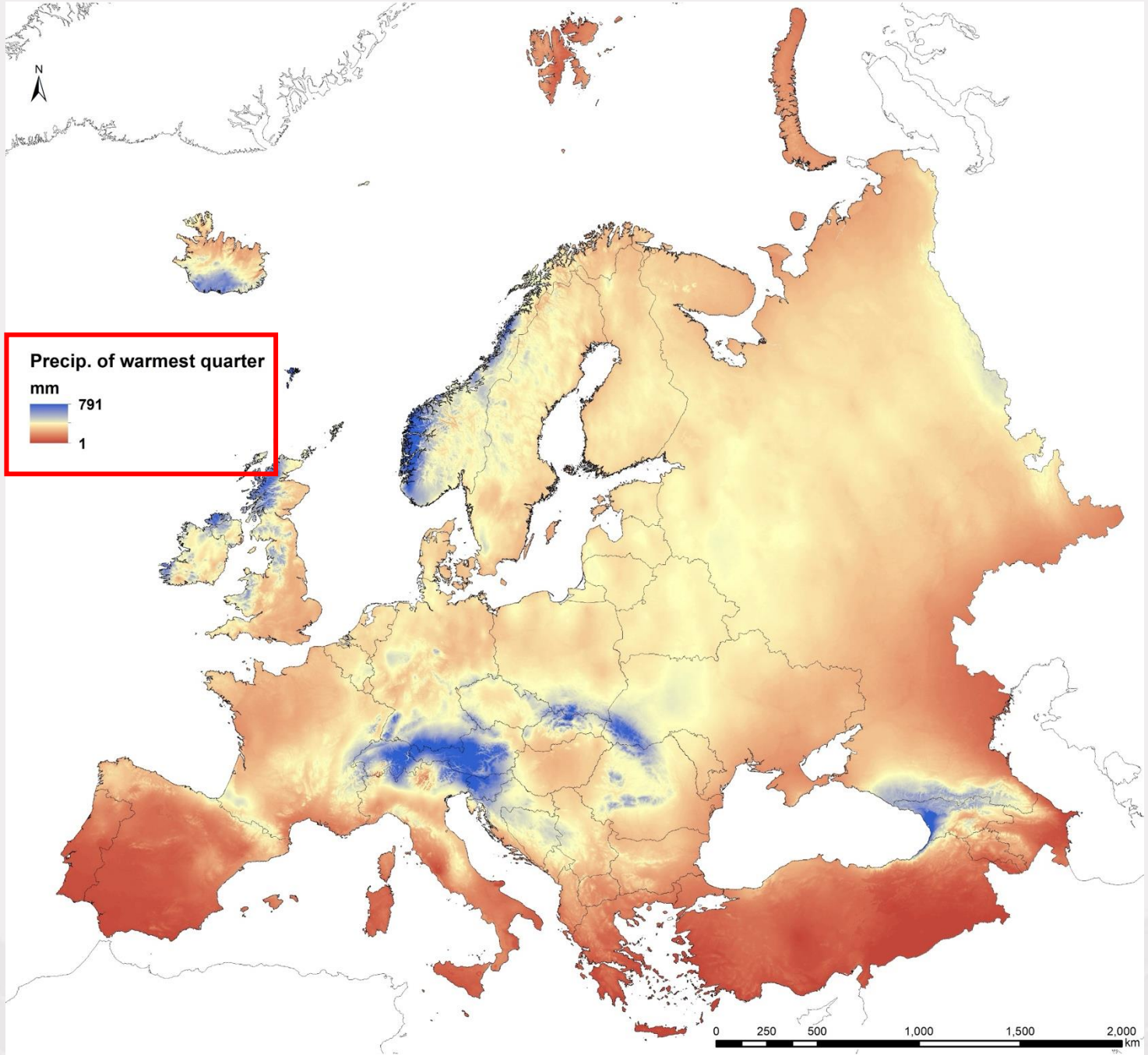
Europe, Precipitation of wettest month. Recent period.



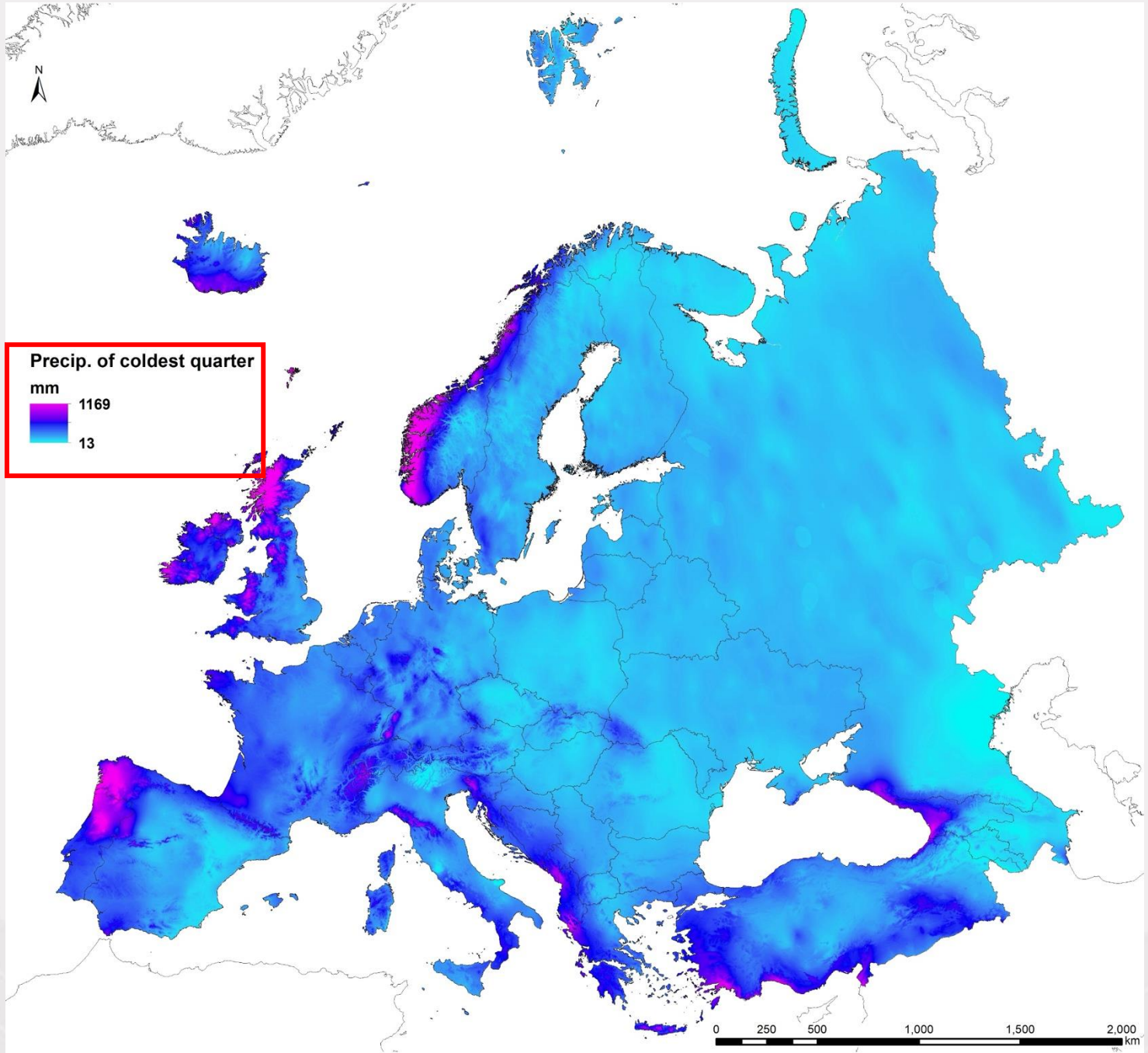
Europe, Precipitation of driest month. Recent period.



Europe, Precipitation of warmest quarter. Recent period.



Europe, Precipitation of coldest quarter. Recent period.



II The second group of GIS climatic layers

The second group of GIS climatic layers includes the preparation of climate maps for the European continent according to the defined climate scenarios**:**

1.1. SSP2-4.5 and **RCP4.5** for three terms: **near-term**, **medium-term**, and **long-term**

1.2. SSP5-8.5 and **RCP8.5** for the three terms: **near-term**, **medium-term**, and **long-term**

These climate scenarios have already been developed for the **STECCI project sites**.

An example of the modelling results under the defined climate scenarios was previously presented for one representative site — **Sarajevo**.

Climate maps based on these scenarios are being prepared for the main climatic elements, including:

Air temperature

a. mean annual air temperature
b. maximum air temperature of the warmest month
c. minimum air temperature of the coldest month
d. mean air temperature of the wettest quarter

Precipitation

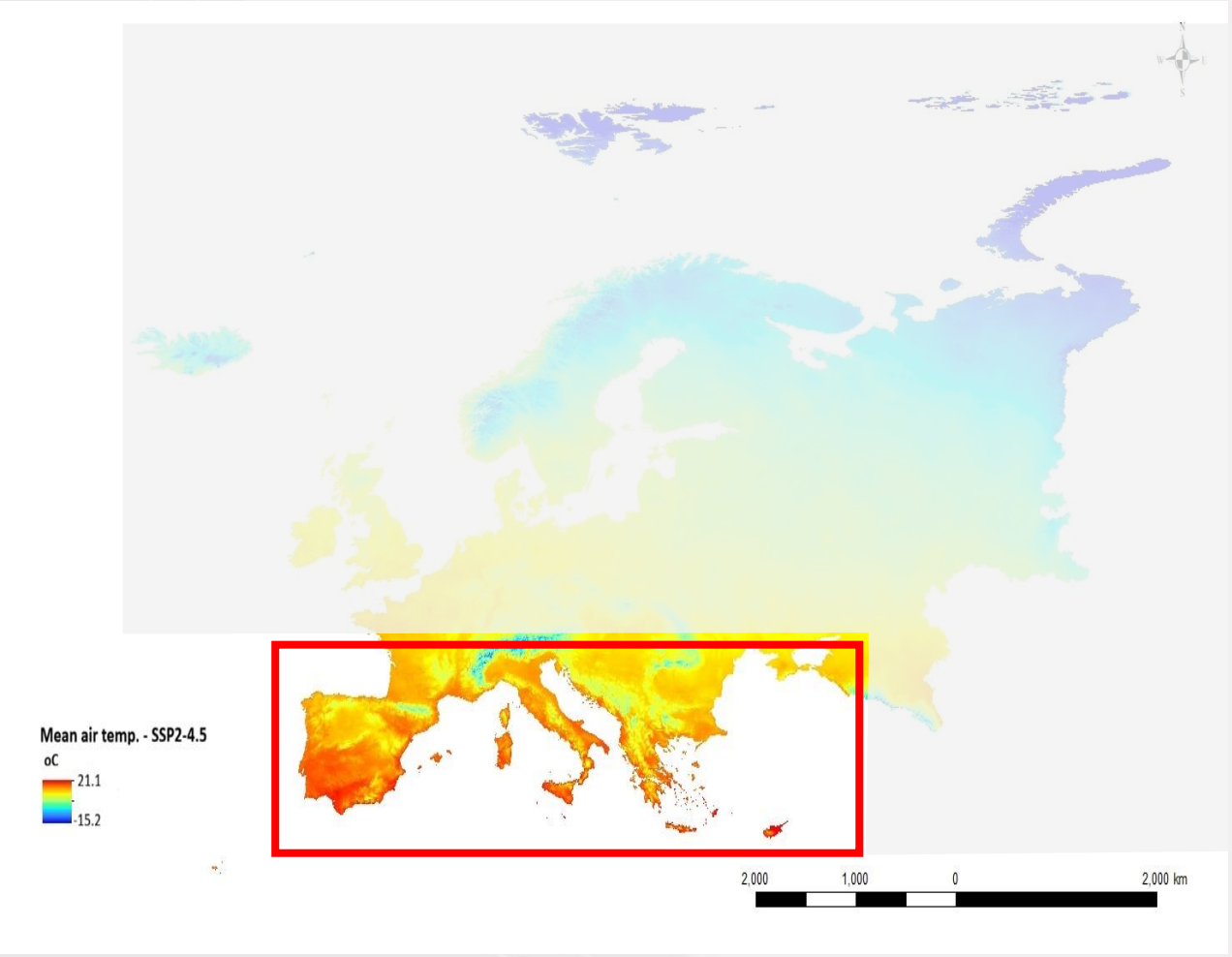
a. mean annual precipitation total
b. mean precipitation total of the wettest month
c. mean precipitation total of the driest month
d. mean precipitation total of the wettest quarter
e. mean precipitation total of the driest quarter
f. mean precipitation total of the warmest quarter
g. mean precipitation total of the coldest quarter

1.3. Climate types map

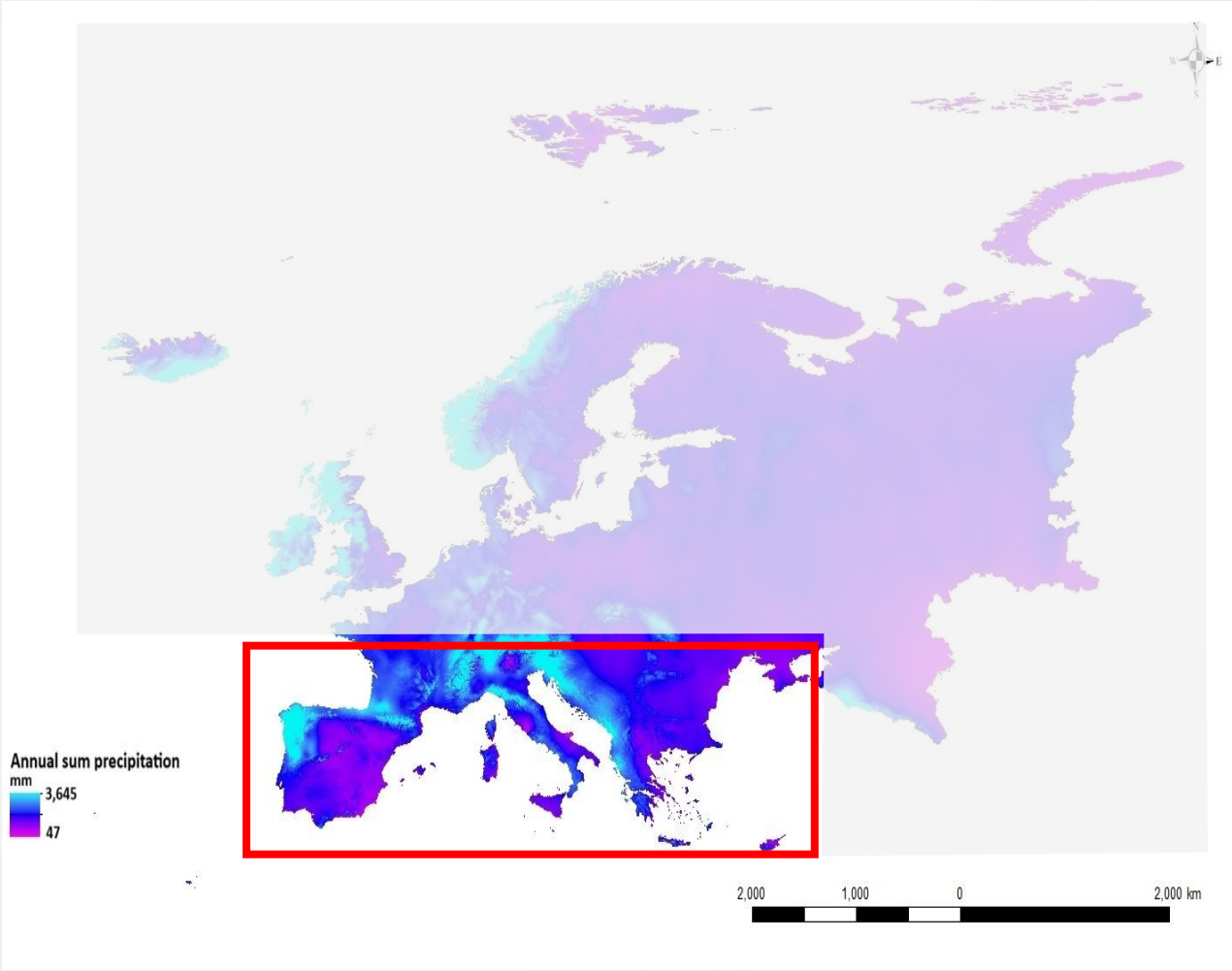
A map of climate types according to the **W. Köppen climate classification** will be prepared for both climate scenario groups.

Example, Mediterranean region

Mean annual air temperatures according to SSP2-4.5 climate scenario – near term for Europe



Annual sum of precipitation according to SSP2-4.5 climate scenario – near term for Europe



III The third group of GIS climatic layers

The third group of GIS climatic layers includes the development of risk maps for stone sacral structures across the European continent according to the previously defined climate scenarios: SSP2-4.5 and SSP5-8.5, as well as RCP4.5 and RCP8.5.

These vulnerability maps will be produced through algorithm-based modelling using several groups of thematic layers:

1. Climate maps (grid format):

air temperature — individual GIS thematic layers for air temperature, as previously presented

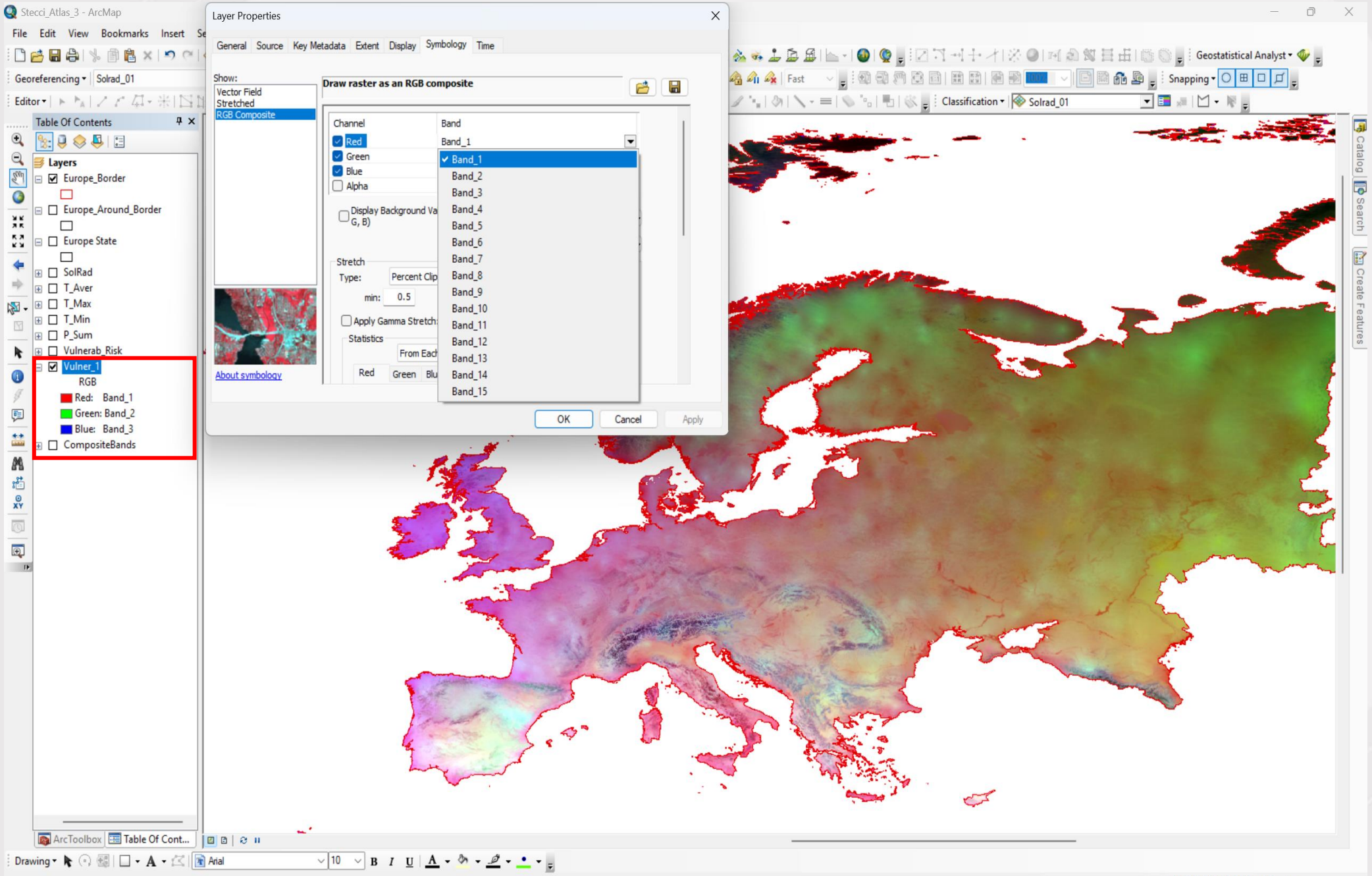
precipitation — individual GIS thematic layers for precipitation, as previously presented

2. Digital Terrain Model (DTM) for the European continent (grid format, spatial resolution 90 m), **including**:

Elevation, slope, aspect …

3. Physical-geographical GIS thematic layers for the European continent (shapefile format), **including**: Geology, tectonics, hydrology, soil, CLC, biogeographical regions …

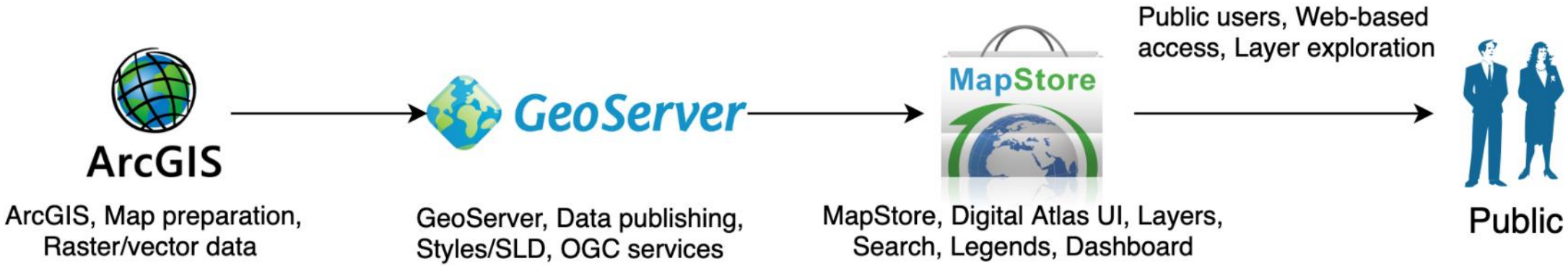
Physical-geographical variables: band combination



Digital STECCI Atlas / Workflow

The digital interactive STECCI Climate Atlas will compile and define the impact of climate change in extreme events on stone sacral structures across Europe according to different climate scenarios. It is essential for the development of the Preservation Guidelines.

Workflow

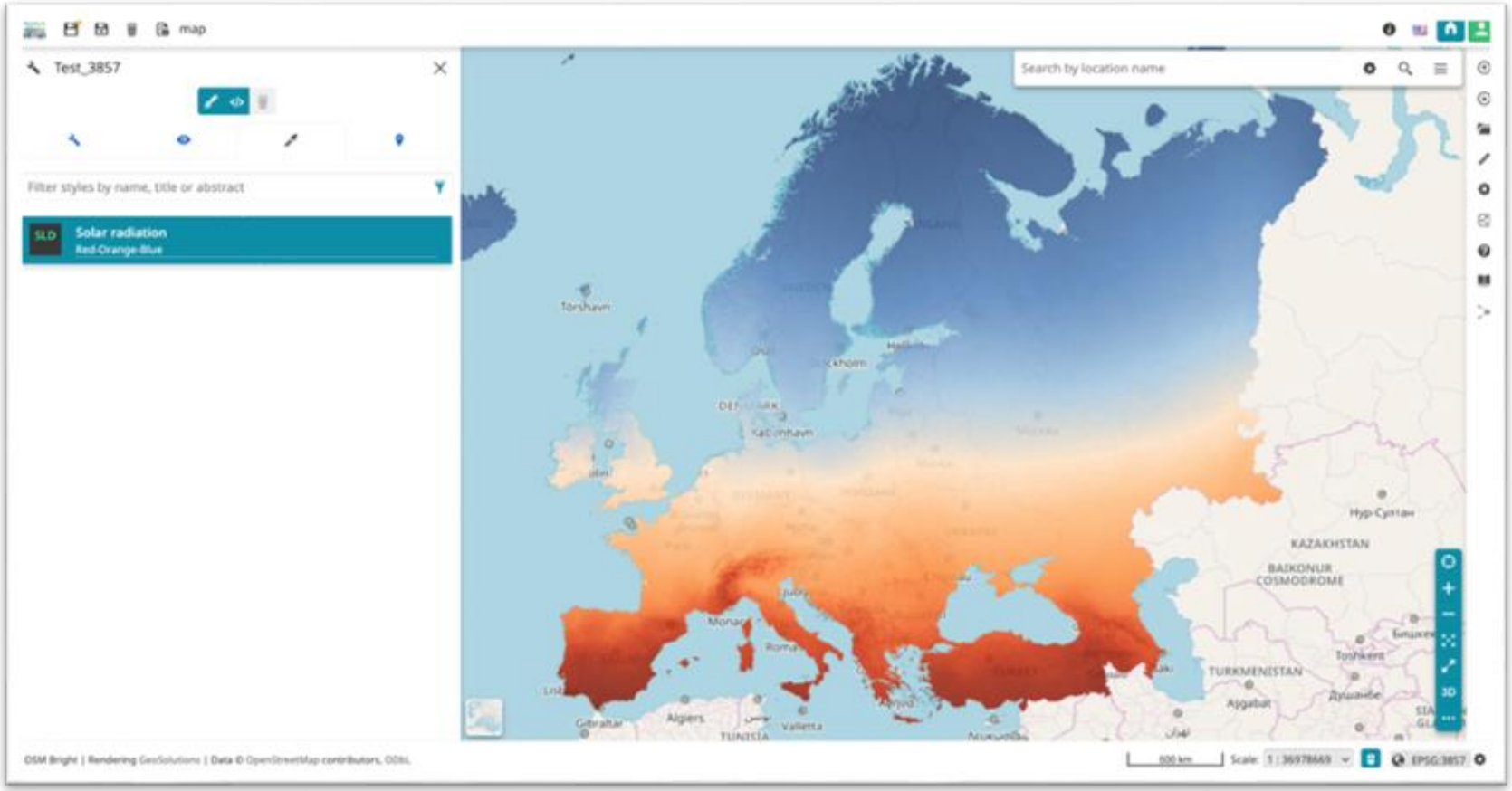


- **Geospatial datasets** are prepared in ArcGIS and published through GeoServer.
- **GeoServer** manages layer styling and serves the data through standard OGC services such as WMS.
- **MapStore** uses these services and presents them through an interactive Digital Atlas interface.
- The workflow connects GIS data preparation, geospatial publishing, and public web visualization through an interoperable well known open-source stack.
- All services and data are stored on self-hosted STECCI servers.

Digital Atlas Interface: MapStore Prototype

Digital Atlas Interface

- testing and configuration phase
- GeoServer–MapStore integration
- raster and vector geospatial layers
- styled thematic map visualisation
- interactive access through OGC web services



The project will produce the **Preservation Guidelines (monitoring protocol and conservation guidelines) for limestone monuments in two climate scenarios**. It will be strengthened with economic tools to facilitate optimal decision-making in protection of cultural heritage .