“Challenges of regional climate change over the Mediterranean - The added value from Regional Climate Models (RCMs)”

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Mean global annual temperature anomalies for the period 1880-2018 with respect to the period 1951-1980.
Spatial distribution of temperature and precipitation changes over the recent past (IPCC, 2013)
Global warming relative to 1850-1900

At the present rate of human-induced warming, global temperatures would reach 1.5°C around 2040.

Observed monthly global average temperatures

Grey plume shows distribution of warming responses to idealised emissions, light grey spanning likely range, dark grey showing central third.

(source: IPCC SR1.5, 2018)
Future projections for temperature and precipitation

(a) Change in average surface temperature (1986–2005 to 2081–2100)

(b) Change in average precipitation (1986–2005 to 2081–2100)
Projected change in extreme at 1.5°C global warming (left) and 2°C global warming (middle) compared to pre-industrial time period (1861-1880), and difference (right; hatching highlights areas in which 2/3 of the models agree on the sign of change): temperature of annual hottest day, TXx (top), and annual coldest day, TNn, (middle), and annual maximum 5-day precipitation, Rx5day (bottom). (source: IPCC SR1.5)
The dependence of risk on the extent of global warming for five Reasons for Concern (RFCs) together with a range of key elements of the Earth system, on the level of global warming. The colour shading indicates the additional risk due to climate change when a temperature level is reached and then sustained or exceeded. Comparison of the increase in risk across RFCs, or across elements, indicates the relative sensitivity to increases in global mean temperature above pre-industrial levels. The RFC component is updated from AR5 with a focus on levels of global warming between 0°C and 2°C global warming. Assessment of risks at higher than 2°C is beyond the scope of the present assessment. (source: IPCC SR1.5)
## Impact of climate factors on cultural heritage

<table>
<thead>
<tr>
<th>Climate parameters</th>
<th>Climate change risk</th>
<th>Physical, social and cultural impacts on cultural heritage</th>
</tr>
</thead>
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<tr>
<td><strong>Atmospheric moisture change</strong></td>
<td>• Flooding (sea, river)</td>
<td>• pH changes to buried archaeological evidence</td>
</tr>
<tr>
<td></td>
<td>• Intense rainfall</td>
<td>• Physical changes to porous building materials</td>
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<td></td>
<td>• Changes in soil chemistry</td>
<td>• Loss of stratigraphic integrity due to cracking and heaving from changes in sediment moisture</td>
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<td></td>
<td>• Ground water changes</td>
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<td></td>
<td>• Increase in time of wetness</td>
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<tr>
<td><strong>Temperature change</strong></td>
<td>• Diurnal, seasonal, extreme events (heat waves, snow)</td>
<td>• Deterioration of facades due to thermal stress</td>
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<tr>
<td></td>
<td>• Changes in freeze-thaw and ice storms</td>
<td>• Freeze-thaw/frost damage</td>
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<tr>
<td><strong>Sea level rises</strong></td>
<td>• Coastal flooding</td>
<td>• Coastal erosion/loss</td>
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<td></td>
<td>• Sea water incursion</td>
<td>• Permanent submersion of low lying areas</td>
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<tr>
<td><strong>Wind</strong></td>
<td>• Wind-driven rain</td>
<td>• Penetrative moisture into porous cultural heritage materials</td>
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<td></td>
<td>• Wind-transported salt</td>
<td>• Structural damage and collapse</td>
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<tr>
<td></td>
<td>• Wind-driven sand</td>
<td>• Deterioration of surfaces due to erosion</td>
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<td></td>
<td>• Winds, gusts and changes in direction</td>
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<tr>
<td><strong>Desertification</strong></td>
<td>• Drought</td>
<td>• Erosion</td>
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<tr>
<td></td>
<td>• Heat waves</td>
<td>• Salt weathering</td>
</tr>
<tr>
<td><strong>Climate and pollution acting together</strong></td>
<td>• pH precipitation</td>
<td>• Stone recession by dissolution of carbonates</td>
</tr>
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<td>• Changes in deposition of pollutants</td>
<td>• Blackening of materials</td>
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<tr>
<td><strong>Climate and biological effects</strong></td>
<td>• Proliferation of invasive species</td>
<td>• Corrosion of metals</td>
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<td>• Increase in mould growth</td>
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<td></td>
<td>• Decline of original plant materials</td>
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<td>• Changes in the natural heritage values of cultural heritage sites</td>
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<td>• Changes in appearance of landscapes</td>
</tr>
</tbody>
</table>
Global Climate Models

- Coupled AOGCMs are the most advanced tools today available for climate simulation.
- The resolution of present day AOGCMs (100 – 300 km) is still too coarse to provide fine scale regional climate information useful for impact studies.
Dynamical processes

Radiative processes

Atmospheric Numerical Modeling

Land-atmosphere interactions

Cloud microphysical processes

Initial conditions from measurements
Regional Climate Models

- **Technique:** A “Regional Climate Model” (RCM) is “nested” within a GCM in order to increase the resolution of a climate simulation.
  - Initial conditions (IC) and lateral boundary conditions (LBC) for the RCM are obtained from the GCM.
- **Strategy:** The GCM is used to simulate the response of the general circulation to large scale forcings, while the RCM is used to simulate the effect of sub-GCM-grid scale forcings and to provide fine scale regional information.
  - The RCM is intended to only enhance the GCM information.
- **Technique inherited from NWP**
Modelled temperature climatology (1975-2000) based on GCMs and RCMs: The effect of resolution

Climate on islands, mountains and coastal areas changes very differently around the Mediterranean Sea and it can only be properly highlighted using a RCM

Precipitation changes over the 21\(^{st}\) century based on RegCM simulation with 10 km x 10 km under A1B scenario
Temperature changes over the 21st century based on RegCM simulation with 10 km x 10 km under A1B scenario

[Map showing temperature changes over the 21st century]
Changes in indices of extremes under A1B scenario 2071-2100 – 1961-1990 – (10 km x 10 km)
Challenges of regional climate change

The Mediterranean (and the surrounded regions) is one of the most sensitive and vulnerable to climate change regions on Earth.

The necessity to exploit the use of vast amount of data produced from existing infrastructures (e.g. earth observations and models, sectoral data) to support intermediary users and end-users and promote the uptake of relevant services and data in response to regional needs.

The need to integrate the different scientific disciplines involved in present and future environmental change in the region.

The need for a holistic approach to efficiently inform policy makers for the mitigation of the risks, support of adaptation strategies and plans, and advise society about the challenges of changing environment.

The need to address regional and local gaps and needs for new market opportunities under a changing environment and facilitate the engagement of regional stakeholders.
Challenges of regional climate change for adaptation and mitigation from the RCMs perspective

To support local/regional climate change impact studies as well as regional adaptation and mitigation strategies it is necessary to use high resolution future climate data from model projections based on RCMs.

There is plenty of climate change data from RCMs in open access databases but restricted usability from non-experts.

There is need for establishing user friendly web application tools for intermediary and end-users as well as policy decision makers.
DEAR-Clima
A Data Extraction Application for Regional Climate

• DEAR-Clima is a user friendly dynamical web application tool that extracts, visualizes and provides time series of essential climate variables and climate indices.

Domain

The domain of the application is the EURO-CORDEX domain which covers the greater area of Europe including the Mediterranean and a part of N.Africa. The spatial resolution of the CORDEX simulations used in this application is 11°x11°. The approximate center of the boundaries is 27°N-72°N and 22°W-45°E, while the center point of the domain lies is 49.68°N and 9.75°E. More information about the domain can be found in EURO-CORDEX website.

Extract Climate Information above Europe and N.Africa (EURO-Cordex Domain) in ~12 km resolution.

Future Projection are based on three Representative Concentration Pathways (RCPs)

More than 32 regional climate simulations to choose from the CORDEX experiments ranging for the period 1950-2100.
DEAR-Clima
A Data Extraction Application for Regional Climate
http://meteo3.geo.auth.gr:3838/

Climate Variables

The climate projection application provides historical and future projections of the following essential climate variables.

- Near surface daily Average air Temperature (°C)
- Near surface daily Maximum air Temperature (°C)
- Near surface daily Minimum air Temperature (°C)
- Near surface Wind Speed (m · s⁻¹)
- Precipitation (mm · day⁻¹)
- Surface Solar Radiation (W · m⁻²)
- Surface Air Pressure (hPa)
- Near surface Specific Humidity (mg · kg⁻¹)

- Near surface stands for ~2m.
- Downward surface solar radiation is set to be positive.

8 Essential Climate Variable to extract and...
# Climate Indices

13 Climate Indices related to Drought, Wet Heat and Cold days.

## Drought

**Consecutive Dry Days (CDD):** Number of consecutive (C) days within a year where precipitation (RR) is lower than 1mm.

\[
CDD = C(\text{RR}_{\text{daily}} < 1\text{mm}) \quad \text{(days)}
\]

**Consecutive Dry Days Periods (CDDP):** Number of periods within a year where precipitation (RR) is lower than 1mm. Each period is constituted of five consecutive (C) dry days.

\[
CDDP = \text{Periods}(\text{C}(\text{RR}_{\text{daily}} < 1\text{mm})) \quad \text{(periods)}
\]

## Wet

**Consecutive Wet Days (CWD):** Number of consecutive (C) days within a year where precipitation (RR) is higher than 1mm.

\[
CWD = C(\text{RR}_{\text{daily}} > 1\text{mm}) \quad \text{(days)}
\]

**Consecutive Wet Days Periods (CWDP):** Number of periods within a year where precipitation (RR) is higher than 1mm. Each period is constituted of five consecutive (C) wet days.

## Cold

**Frost Days (FD):** Number of days within a year where daily minimum temperature (Tmin) is below 0°C.

\[
FD = T_{\text{min,daily}} < 0^\circ\text{C} \quad \text{(days)}
\]

**Consecutive Frost Days (CFD):** Maximum number of consecutive (C) days within a year where daily minimum temperature (Tmin) is below 0°C.

\[
CFD = C(\text{T}_{\text{min,daily}} < 0^\circ\text{C}) \quad \text{(days)}
\]

**Ice days (ID):** Number of days within a year where daily maximum temperature (Tmax) is below 0°C.

\[
ID = C(\text{T}_{\text{max,daily}} < 0^\circ\text{C}) \quad \text{(days)}
\]

**Summer Days (SU):** Number of days within a year where daily maximum temperature (Tmax) is greater than 25°C.

\[
SU = T_{\text{max,daily}} > 25^\circ\text{C} \quad \text{(days)}
\]

**Consecutive Summer Days (CSU):** Maximum number of consecutive (C) days within a year where daily maximum temperature (Tmax) is greater than 25°C.

\[
CSU = C(T_{\text{max,daily}} > 25^\circ\text{C}) \quad \text{(days)}
\]

**Hot Days (HD):** Number of days within a year where daily maximum temperature (Tmax) is greater than 35°C.

\[
HD = C(T_{\text{max,daily}} > 35^\circ\text{C}) \quad \text{(days)}
\]

**Tropical Nights (TR):** Number of days within a year where daily minimum temperature (Tmin) is greater than 20°C.

\[
TR = C(T_{\text{min,daily}} > 20^\circ\text{C}) \quad \text{(days)}
\]
Temperature change at Thessaloniki

Temperature 2m, E-11 (Lon:23.008, Lat:40.665, Alt:245.1m)

Precipitation, E-11 (Lon:23.008, Lat:40.665, Alt:245.1m)
Thanks for your attention
Σενάρια Εκπομπών - IPCC 2013
Context

• For Adaptation to Climate Change (ACC) is essential the use of high resolution future climate data from model projections.
• There is plenty of climate change data in open access databases but restricted usability from non-experts.
• There is need for establishing user friendly web application tools for intermediary and end-users.

Objectives

• The DEAR-Clima is a dynamical web application tool that visualizes and extracts time series of essential climate variables and climate indices for intermediary and end-users working on ACC as well as by researchers working on climate change impact studies.
• It can be also used for educational activities by students.
The data are based on high horizontal resolution Regional Climate Model (RCM) simulations from the CORDEX research program with a high spatial resolution (0.11°) over the European domain and cover a time period from 1950 to 2100.

The historical period of each experiment refers to 1950-2004, while the future period is 2006-2100 under the influence of three Representative Concentration Pathways (RCPs) adopted by the IPCC for its fifth Assessment Report (AR5); rcp26, rcp45 and rcp85.

The simulation experiments are a product of various RCMs driven by several Global Climate Models (GCMs).
## DEAR-Clima application tool

### List of Essential Climate Variables (ECVs) and Climate Indices (CI)

<table>
<thead>
<tr>
<th>Climate Indices</th>
<th>Relevance</th>
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</thead>
<tbody>
<tr>
<td>CI1  Mean near surface temperature</td>
<td>Fundamental</td>
</tr>
<tr>
<td>CI2  Precipitation rate</td>
<td>Fundamental</td>
</tr>
<tr>
<td>CI3  Maximum near surface temperature</td>
<td>Fundamental, extremes</td>
</tr>
<tr>
<td>CI4  Minimum near surface temperature</td>
<td>Fundamental, extremes</td>
</tr>
<tr>
<td>CI5  Wind speed at 10m, 50m, 100m and 200m</td>
<td>Fundamental, Energy, natural disasters</td>
</tr>
<tr>
<td>CI6  Surface absorbed solar radiation</td>
<td>Fundamental, Energy, Tourism, Agriculture</td>
</tr>
<tr>
<td>CI7  95th percentile of rain day amounts</td>
<td>Extremes, natural disasters</td>
</tr>
<tr>
<td>CI8  95th percentile of wind speed at 10 m</td>
<td>Extremes, natural disasters</td>
</tr>
<tr>
<td>CI9  Annual greatest 5-day total rainfall</td>
<td>Extremes, natural disasters</td>
</tr>
<tr>
<td>CI10 Fraction % of total rainfall from events &gt; long-term P90</td>
<td>Extremes, natural disasters</td>
</tr>
<tr>
<td>CI11 Number of events &gt; long-term 90th percentile of rain days</td>
<td>Extremes, natural disasters</td>
</tr>
<tr>
<td>CI12 Number of frost days Tmin &lt; 0 degC</td>
<td>Extremes</td>
</tr>
<tr>
<td>CI13 Heat Wave Duration Index</td>
<td>Agriculture, Tourism</td>
</tr>
<tr>
<td>CI14 Standardized Precipitation Index (SPI)</td>
<td>Agriculture, Water resources</td>
</tr>
<tr>
<td>CI15 Potential evaporation</td>
<td>Agriculture</td>
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<td>CI16 Growing season duration (GSD)</td>
<td>Agriculture</td>
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<td>CI17 Tourism Climate Index (TCI)</td>
<td>Tourism</td>
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<td>CI18 Snow depth (SnowD)</td>
<td>Tourism</td>
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<td>CI19 Heating Degree Day (HDD)</td>
<td>Energy</td>
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<tr>
<td>CI20 Cooling Degree Day (CDD)</td>
<td>Energy</td>
</tr>
</tbody>
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