ADRIADAPT D.3.2.1

Release of a preliminary set of climate data and indicators made available through the project platform

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1 Abbreviations

AR5:	5th Assessment Report of the Intergovernmental Panel on Climate Change
CMIP5:	5th phase of the Coupled Model Intercomparison Project
CMCC:	Fondazione Centro euro-Mediterraneo sui Cambiamenti Climatici
GCMs:	General Circulation Models
IPCC:	Intergovernmental Panel on Climate Change
NetCDF:	Network Common Data Form
RCMs:	Regional Climate Models
RCP4.5:	Representative Concentration Pathway to a radiative forcing of 4.5 W/m2 at the end of 2100 wrt preindustrial values
RCP8.5:	Representative Concentration Pathway to a radiative forcing of 8.5 W/m2 at the end of 2100 wrt preindustrial values

SD: Statistical Downscaling

2 Introduction

This document (D3.2.1) provides a preliminary description of the climate data that has been delivered by CMCC to the ADRIADAPT project users. Within ADRIADAPT project, data are provided for the period from 1951 to 2100, following historical forcing up to 2005 and two different possible radiative emission scenarios to the end of the century: a business as usual one and a more moderate one. In this document we will focus on data evaluation over the historical period only. Future projection evaluation will be the subject of D3.3.1 “Detailed quantification of climate change signal in the region of interest with special emphasis on severe impacting events” due at month 24. High resolution (12.5km X 12.5km for each simulated grid cell) meteorological fields (temperature, wind, precipitation among others) have been made available in a common format over the domain defined within ADRIADAPT. Based on these fields, a series of extreme events indicators at the daily time scale have been identified in D3.1.1 “Definition of a set of climate change indicators for stakeholders“ and part of these indicators are described in this document and compared to observational data sets. A complete description of the parameters identified by ADRIADAPT stakeholders - within the list of parameters suggested in D3.1.1 – will be the subject of D3.2.2 document due at month 18. A set of four Regional Climate Models (RCMs) participating to the EURO CORDEX project on the EUR-11 grid is used.

3 Description of Models and parameters

One of the ways to investigate the climate system and its variability is through climate models. Considering the global scale, a climate model can be an atmosphere (or ocean)-only general circulation model (GCM) or a fully coupled general circulation model (CGCM). To improve the ability of a climate model in representing small-scale features, instead of a general circulation model, regional climate model (RCM) and statistical downscaling technique (SD) can be used: this approach makes it possible to increase the spatial resolution, reducing the extension of the domain considered. In fact, the performance and the spatial resolution of GCMs have continuously improved in the recent years, but the typical state of the art spatial scale is still too coarse to realistically reproduce present climate and eventually project climate change signals on local scales, especially in the presence of complex orography (Rummukainen, 2010; IPCC, 2001) such as over the European domain.

The EURO-CORDEX (COordinated Regional climate Downscaling EXperiment) (Nikulin et al., 2012) on the 12.5 km EUR-11 spatial domain is one source of data foreseen within ADRIADAPT and in the next chapters we will evaluate model ability in representing the climate over the ADRIADAPT domain (Figure 1), not only in terms of averages but also extremes, comparing them with observational data-sets.

EURO-CORDEX is the European branch of the international CORDEX (COordinated Regional climate Downscaling EXperiment) initiative, which is sponsored by the World Climate Research Program (WRCP) to organize an internationally coordinated framework to produce improved regional climate change projections, through regional climate models, for all land regions world-wide (http://www.euro-cordex.net/). The CORDEX-results serve as input for climate change impact and adaptation studies within the timeline of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) and beyond. The experiments used to provide the RCM dataset described in this report are based on the standard setup of the model for the CORDEX ensemble simulations (Nikulin et al., 2012, Vautard et al. 2013) over the EUR-11 domain thus over the European domain with a horizontal resolution of 12.5 km. This means that the RCMs compute the “climate equations” over each grid cell (one cell represent an area of 12.5km x 12.5km), based on previous values (the model time step is of the order for few minutes) and adjacent cell values. The model is able to evolve in time, with the only constrain of radiative forcing (atmospheric concentration of greenhouse gasses, ozone and aerosols) and boundary conditions: ocean conditions are expected at the lower boundary of the RCM (such as sea surface temperature, current velocities, etc.) and atmospheric conditions (temperature, wind, water fluxes, etc.) of the surrounding area are expected at the border of the cube on which the model is planned to simulate. As already stated in this way the model is able to evolve in time, providing also long term time series of climate data, based on different potential assumptions in terms of radiative forcing.

Four RCMs are considered in this contest (Scoccimarro et al. 2017). Table 1 lists the considered RCMs. In Table 1 the list of the driving GCMs, furnishing boundary conditions to the relative RCM is also provided.

Table 2 lists the raw and derived fields that we aim to compare to observational results over the historical period in the current document. This is a subsample of the Table 2 and Table 3

parameters defined in D3.1.1. A more extended evaluation will be provided in next deliverable, including also the results derived from the statistical downscaling model(SD) applied over Cervia and Savio Valley municipalities Union. The performance of the SD will be quantified at seasonal level, in terms of: Spearman rank-correlation coefficient, which is the correlation coefficient calculated on the ranks of the observed and simulated time series, and BIAS, computed between observed and simulated time series (Tomozeiu et al.,2007).
Anyway, at this stage, all of the raw data required for the computation of derived indices are already available on the CMCC ftp server (see below for ftp credentials).

Model name	**Driving GCM**	**Institute**
SMHI-RCA4	CNRM-CM5	Swedish Meteorological and Hydrological Institute, Rossby Centre
KNMI-RACMO22E	ICHEC-EC-EARTH	Royal Netherlands Meteorological Institute
INERIS-WRF331F	IPSL-CM5A-MR	IPSL (Institut Pierre Simon Laplace) and INERIS (Institut National de l Environnement industriel et des RISques)
CNRM-ALADIN53	CNRM-CM5	Centre National de Recherches Meteorologiques

Table 1: Regional Climate Models involved in ADRIADAPT data collection (same as Table 1 in D3.1.1).

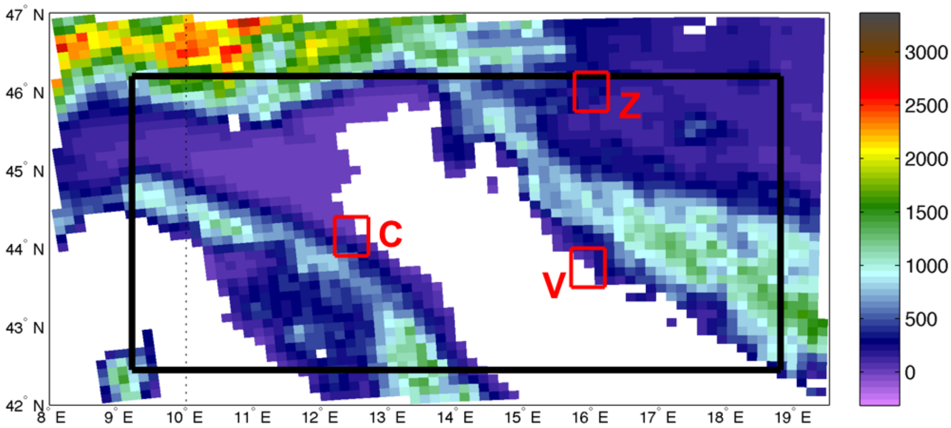

Figure 1: Domain selected (black contour) for the provision of climate (table 2) and extreme (table 4) parameters within ADRIADAPT. Red boxes indicate three sub-regions (C=Cervia, V=Vodice,Z= Zagreb) considered in the next sections. Colors represent the local orography. Units are [m]. (same as Figure 3 in D3.1.1).

The data format used is NetCDF (http://www.unidata.ucar.edu/software/netcdf/). NetCDF is an abstraction that supports a view of data as a collection of self-describing, portable objects that can be accessed through a simple interface. Array values may be accessed directly, without knowing details of how the data are stored. Auxiliary information about the data, such as what units are used, is stored with the data. Generic utilities and application programs can access NetCDF datasets and transform, combine, analyse, or display specified fields of the data.
Data are now available through the CMCC ftp server (download.cmcc.bo.it – user and password sent privately to the ADRIADAPT partner reference person) and, at least partially, uploaded on the ADRIADAPT knowledge platform.

Field Description (the corresponding code in D3.1.1, table 4, is also indicated)	**Field Acronym**	**Vertical level**	**Field Unit**	**Relative validation figures**
2 meter Air Temperature	tas	2 meter	[°C]	2,3,4
99 percentile of temperature: rare events of high temperature (7)	tas_99 (about 100 events in 30y)	2 meter	[°C]	5
99.9 percentile of temperature: extremely rare events of high temperature (7bis)	tas_99.9(about 10 events in 30y)	2 meter	[°C]	6

99 percentile of max daily temperature: rare events of high temperature (8)	tasmax_99 (about 100 events in 30y)	2 meter	[°C]	7
99.9 percentile of max daily temperature: extremely rare events of high temperature (8bis)	tasmax_99.9 (about 10 events in 30y)	2 meter	[°C]	8
99.9 percentile of Perceived Temperature: extremely rare events (20bis)	Humidex_99.9(about 10 events in 30y)	2 meter	[]	9
Precipitation	pr	Surface	[mm/d]	10,11,12
Extreme precipitation (1)	pr_99	Surface	[mm/d]	13
Intense Precipitation (2)	pr_95	Surface	[mm/d]	14

Table 2: List of meteorological fields investigated in this document over the historical period. (in brackets the relative parameter number consistent with table 2 of D3.1.1)

The indices presented in Table 2 are selected within the list defined in D3.1.1 to describe the frequency and the intensity of extreme events. The extreme events are here defined based on threshold percentile (STARDEX (http://www.cru.uea.ac.uk/stardex).
In order to give an idea on the percentile approach, considering daily data, over the whole year, the 99 percentile of a 30-year time series of temperature data, corresponds to the temperature value reached in about 100 days only: about 4 days in a year. For the identification of even more rare and potentially impacting events, also the 99.9 percentile is taken into account for some of the investigated parameters, representing events happening 10 times only in a 30y time series of daily values: one event every three years.
In other words the 95th/99th/and 99.9th percentiles are used to represent moderately rare / rare / extremely rare events in the right tail of the event distribution. In this document we present some of the parameters defined within the D3.1.1 in terms of comparison with observational data sets. In particular temperature and precipitation data and derived parameters are compared with E-OBS observational data set (Cornes et al. 2018), a gridded version of the ECA dataset with daily temperature, precipitation and pressure fields. The ECA dataset contains series of daily observations at meteorological stations throughout Europe and the Mediterranean.
On the other hand, parameters derived also based on relative humidity, such as the humidex index used to represent the perceived temperature, are compared to JRA-55 reanalysis data set (Kobayashi et al 2015), since there are no gridded observations of relative humidity. A reanalysis product is obtained running a General Circulation Model, adapting, time step after time step, the "computed climate" to the observed one, based on Data Assimilation processes building on available observations.

This is done to increase the spatial and temporal resolution of climate data, remaining as much as possible close to the observed (coarser) values. JRA-55 reanalysis cover the entire globe. The Japanese 55 year re-analysis data set has a spatial resolution of 0.5◦ longitude by 0.5◦ latitude and 60 vertical levels with a top layer at 0.1 hPa. The data assimilation system in JRA-55 has been improved since the time of the production of the prior JRA-25 (Onogi et al 2007), including the introduction of a new radiation scheme, and a 4D-Var assimilation scheme, a state of the art algorithm which uses observations to update the past in addition to the current model state. The use of a reanalysis data set is necessary to obtain relative humidity gridded data at the daily time frequency. Noteworthy 2m temperatures from JRA-55 reanalysis compare favorably well with the observed values (Simmons et al 2017) over Europe (not shown).

For the sake of simplicity we will refer to JRA-55 climate fields as 'observations' in the rest of the paper.

This document is intended as a first evaluation report for the validation and identification of extreme climate parameters that can be suitable for future scenario investigation (deliverable D3.3.1), within the bunch of indicators listed in deliverable 3.1.1. Extended maps covering the whole ADRIADAPT domain are shown, and ADRIADAPT stakeholders are invited to identify sub-regions suitable for the computation of time series of the selected parameters up to 2100 under different potential scenarios that will be considered in D3.3.1.

4 Temperature based indices evaluation over the present period

The aim of this section is to evaluate EURO-CORDEX models ability in representing averages and extremes of the main fields considered when investigating heat stress conditions. The considered period for comparison is 1976:2005. Anyway This period could be shortened to 1986:2005 for the computation of future changes in D3.3.1 “Detailed quantification of climate change signal in the region of interest with special emphasis on severe impacting events”. Since in EURO-CORDEX EUR-11 effort, CMIP5 (5th Coupled Model Intercomparison Project) General Circulation Model output is used to force historical and future scenario regional simulations, the historical period ends in 2005 instead of 2019 as expected. Once new CMIP6 simulation will start to be available, this upper limit for the “historical period” will be set to 2014.

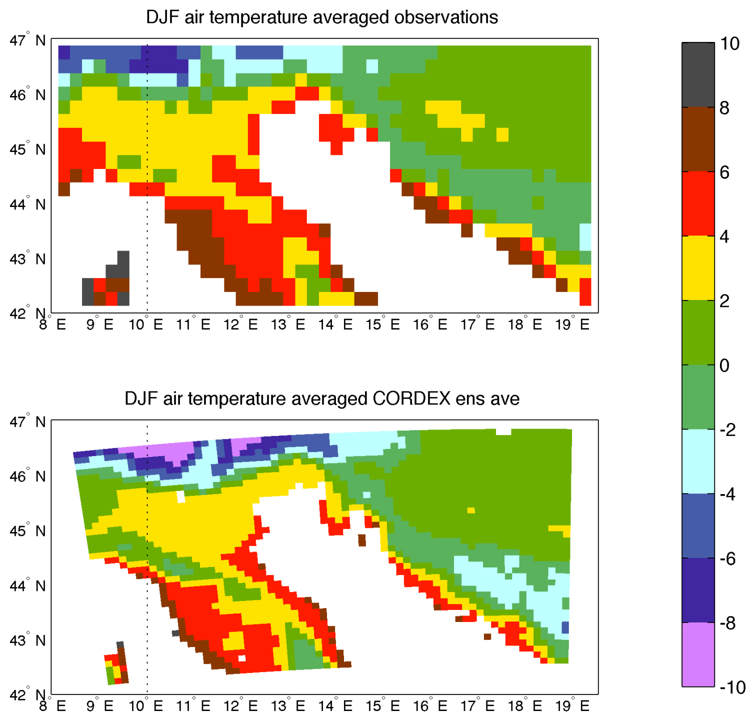

Figure 2: Winter (December to February – DJF) averaged temperature over the 1976:2005 period. Upper panel shows observations (E-OBS) and lower panel shows the 4 members EURO-CORDEX ensemble average. Units are [°C].

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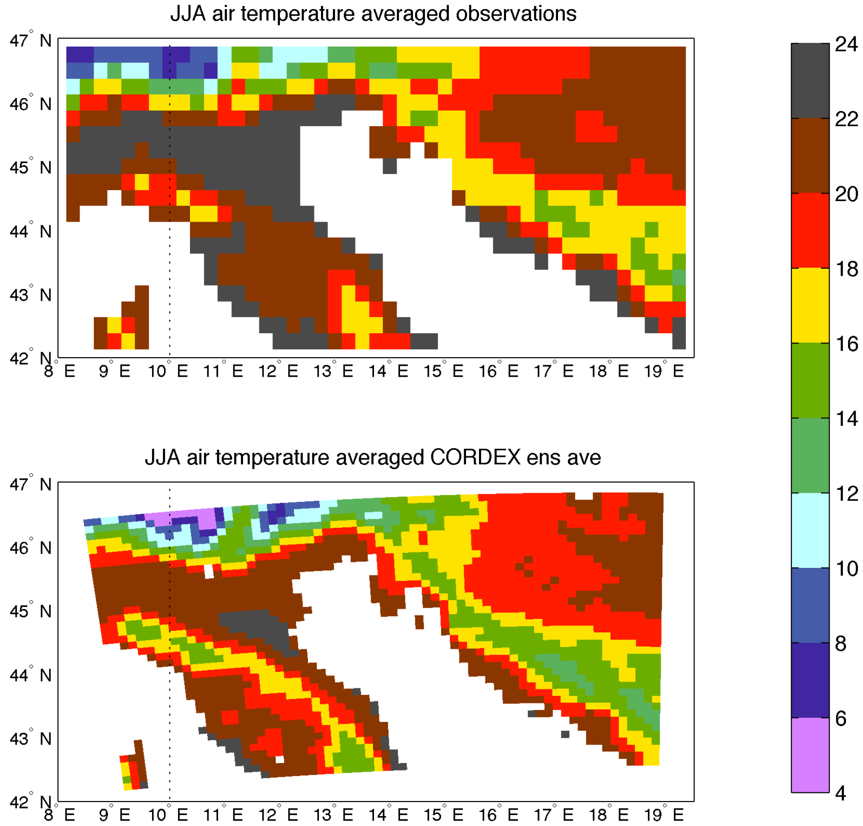

Figure 3: Summer (June to August – JJA) averaged temperature over the 1976:2005 period. Upper panel shows observations (E-OBS) and lower panel shows the 4 members EURO-CORDEX ensemble average. Units are [°C].

This is due to the delay induced to complete the whole modelling chain, from the creation of updated observational data set for greenhouse gasses and aerosols, to their usage as radiative forcing in running GCMs, than RCMs, etc. In any case using 30year (1976:2005) period is sufficient to capture the entire internal variability of the system, thus to make a robust evaluation of mean climate and climate variability over the region.
Not only daily temperature (tas) is considered but also maximum daily temperature (tasmax), in order to consider the short term heat stress conditions during the day. In the following figures we compare observational values (upper panel) to modelled results as obtained averaging the four EURO-CORDEX models output (ensemble average, lower panel). Previous studies highlighted that over the European domain, different temperature biases (a bias is a deviation with respect to the observations) are expected over different regions. Anyway, over the ADRIADAPT domain

such biases are really small at least during winter (Figure 2). As shown in figure 2 models are realistically representing winter temperature, but over the Alps, with a small negative bias (temperature colder than observed) during summer.

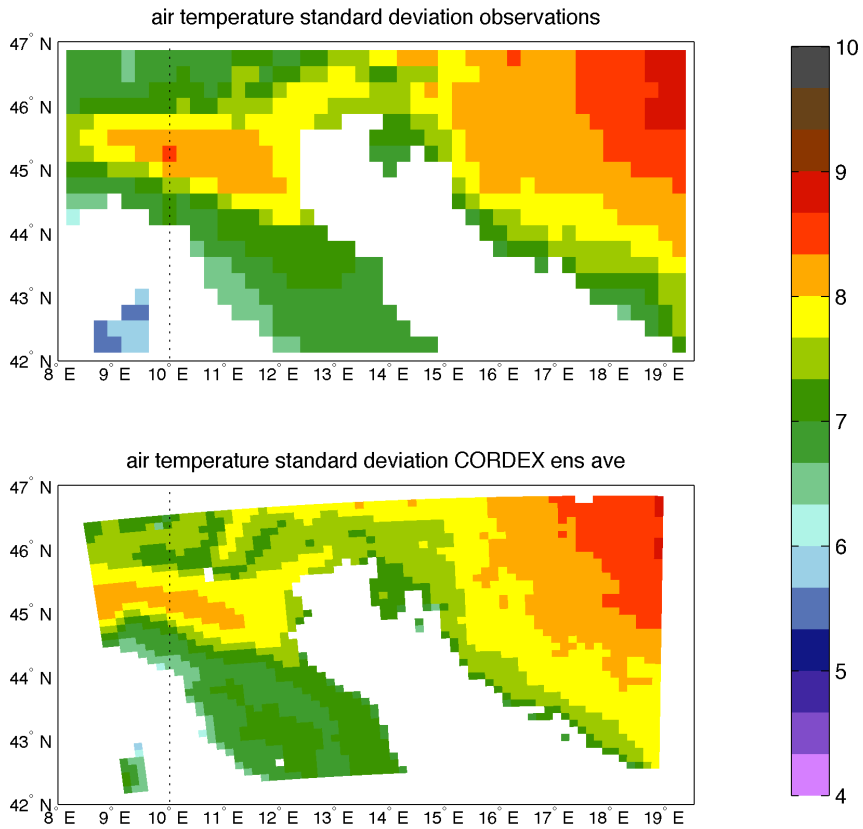

Figure 4: Standard deviation of daily temperature over the 1976:2005 period. Upper panel shows observations (E-OBS) and lower panel shows the 4 members EURO-CORDEX ensemble average. Units are [°C].

In both seasons, models are good in representing air temperature along the coast and also the standard deviation of the daily time series over the whole 1976-2005 period looks very similar to the observed one (Figure 4).

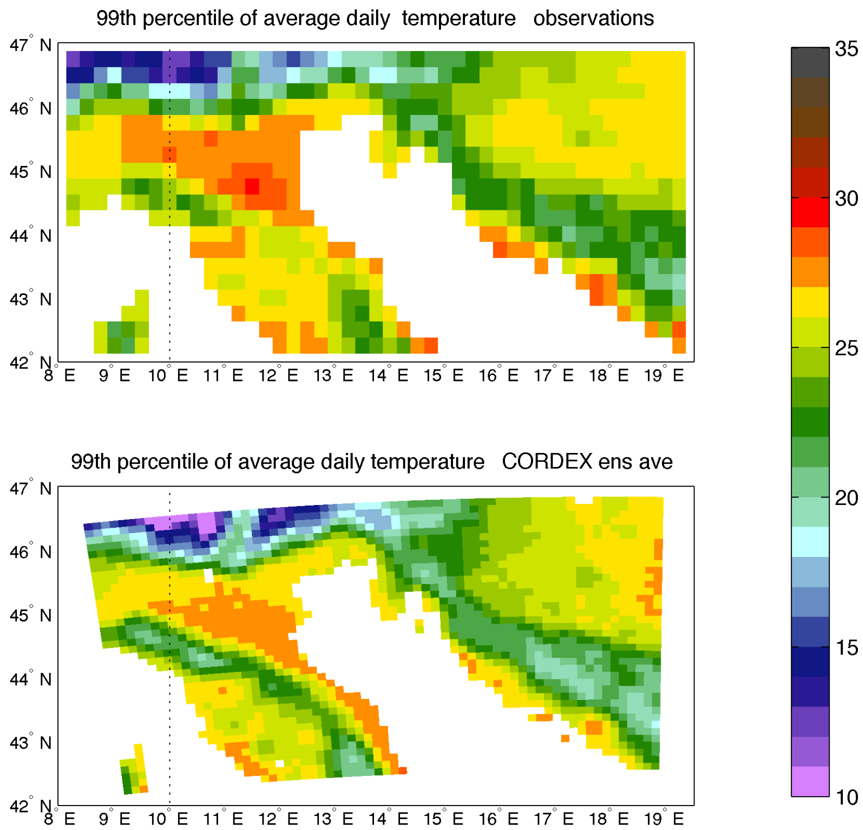

Figure 5: Rare events (99th percentile) of high daily temperature over the 1976:2005 period. Upper panel shows observations (E-OBS) and lower panel shows the 4 members EURO-CORDEX ensemble average. Units are [°C].

When focusing on rare events (99th of daily time series over the 30 year period, Figure 5), EURO-CORDEX models still perform reasonably well, with a tendency to underestimate over the Alps, Apennines and Emilia Romagna region. On the other hand the Adriatic coastal domain is well represented.

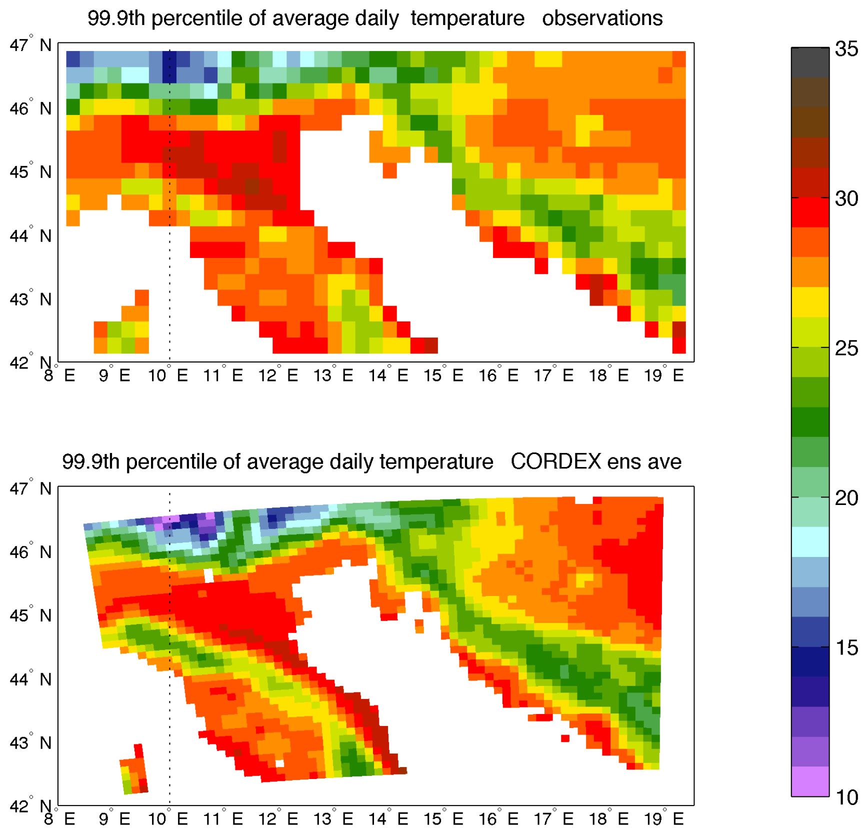

Figure 6: Extremely rare events (99.9th percentile) of high daily temperature over the 1976:2005 period. Upper panel shows observations (E-OBS) and lower panel shows the 4 members EURO-CORDEX ensemble average. Units are [°C].

A similar bias is evident also when focusing on extremely rare events (99.9th percentile) of daily temperature (Figure 6), but once again along the coasts model results are impressively similar to observations.

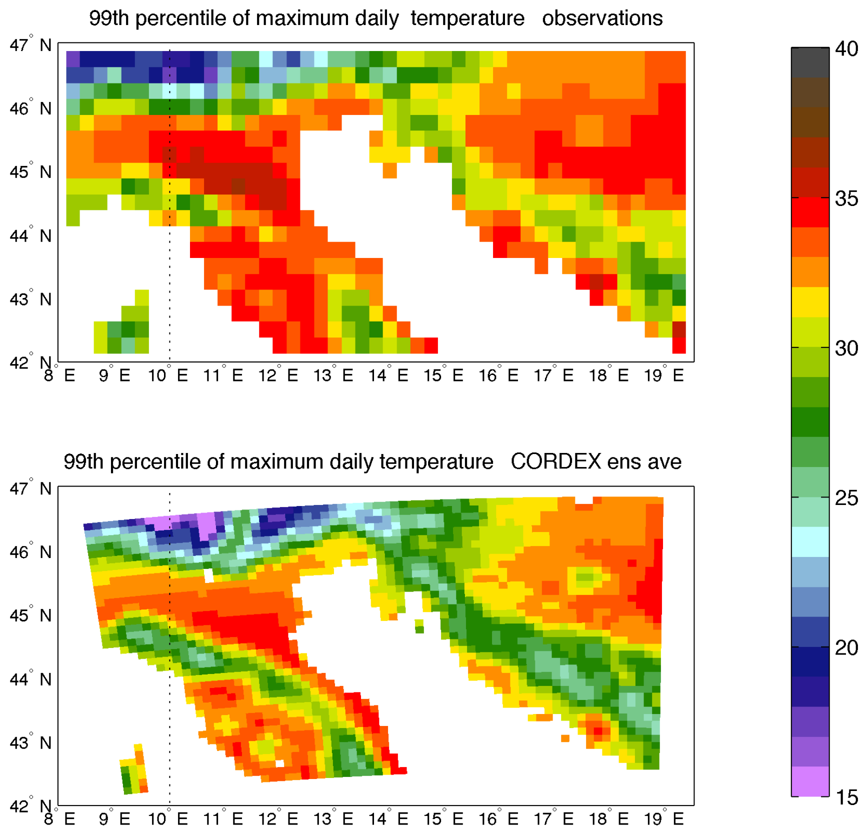

Figure 7: Rare events (99th percentile) of high maximum daily temperature over the 1976:2005 period. Upper panel shows observations (E-OBS) and lower panel shows the 4 members EURO-CORDEX ensemble average. Units are [°C].

A more representative parameter for sub-daily stress conditions is the maximum daily temperature (tasmax), instead of averaged daily temperature (tas): some relative statistics are shown in Figure 7 (rare events - 99th percentile) and figure 8 (extremely rare events – 99.9th percentile). Bearing in mind that we are looking at numbers representative of a wide area (about 12.5x12.5 km box for models and 25x25 km for observations), extremely rare events are well captured by the models with values up to 40 Celsius degrees also along the coasts.

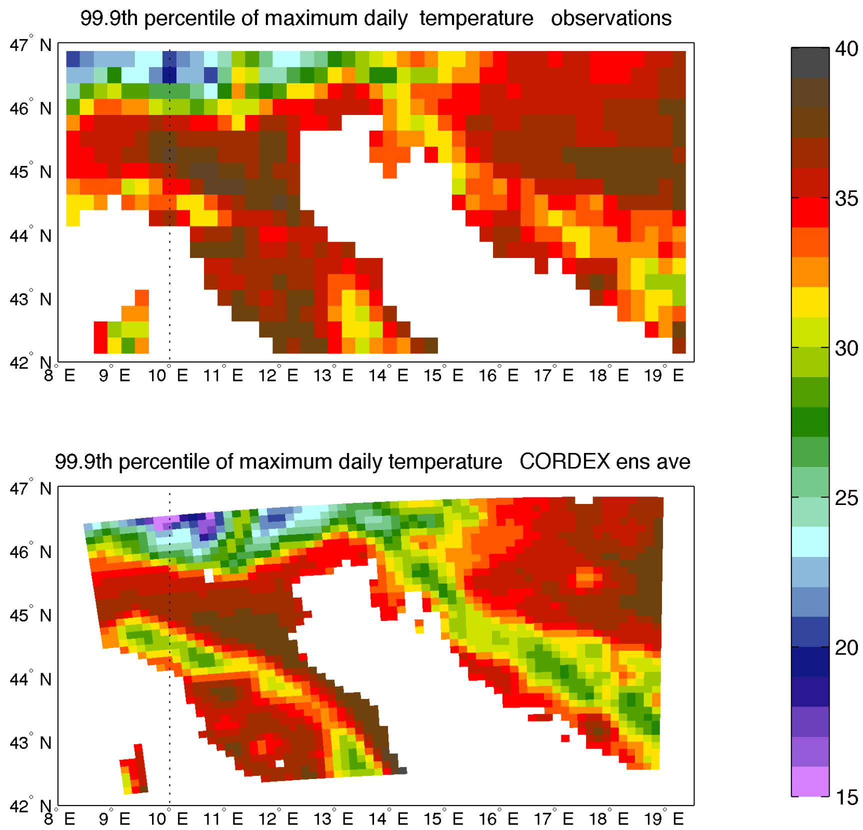

Figure 8: Extremely rare events (99.9th percentile) of high maximum daily temperature over the 1976:2005 period. Upper panel shows observations (E-OBS) and lower panel shows the 4 members EURO-CORDEX ensemble average. Units are [°C].

Temperature only based indices are not sufficient to describe human heat disease. Once human body temperature higher than 37oC is reached, internal heat needs to be released from the body into the environment, via evaporation of sweat. In high humidity conditions, however, sweat evaporation is much less efficient than under dry conditions, and any other physiological changes cannot prevent the core body temperature from reaching a dangerous level. It is well known that heat stress increases mortality, but also a clear effect of high perceived temperature on working/exercise capacity and cognitive performances has been demonstrated (Scoccimarro et al. 2017). In addition, excessive heat exposure affects not only individuals but also the local economy through impacts on worker productivity (Levy and Patz, 2015).

Previous works suggest an important role of humidity particularly pronounced in the southern and eastern Mediterranean regions (Diffenbaugh et al. 2007),

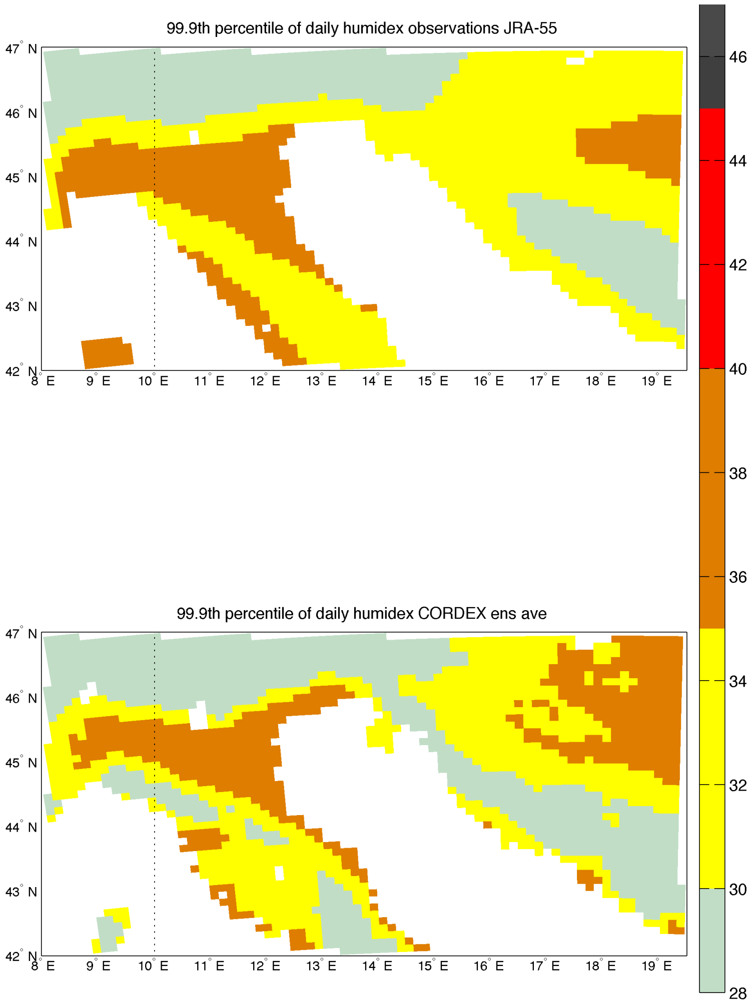

Figure 9: Extremely rare events (99.9th percentile) of perceived temperature (humidex index) over the 1976:2005 period. Upper panel shows observations (JRA-55) and lower panel shows the 4 members EURO-CORDEX ensemble average. The five colors (gray/yellow/orange/red/brown) indicate no discomfort/some discomfort/great discomfort/huge discomfort/really dangerous conditions, respectively.

thus we want to quantify the contribution that air humidity has in the modulation of perceived temperature under extremely warm conditions (99.9 percentile of daily time series over the 30 year period) over the ADRIADAPT region, to understand if this index should be taken into account in the deliverable D3.3.1 investigating future projections. In order to represent the human perceived temperature, different indices have been defined and in this report we consider the *humidex* (Masterton and Richardson, 1979), a basic discomfort index computed through *2-meter air temperature* (tas) and *relative humidity* parameters, and it is used to mimic perceived temperature by the human body. The resulting values do not refer to any measurable temperature, but can help in the definition of human heat disease associated with high temperatures.

The index is defined as: *humidex* = T + 5/9 · (e-10)

where: e ={6.112·10^(7.5·T/[237.7+T]) ·RH/100}

T = 2-meter air temperature [oC]

RH = 2-meter relative humidity [%]

Five main categories are defined to represent different level of heat disease:

humidex < 30	No Discomfort
30 <= *humidex* < 35	Some Discomfort
35 <= *humidex* < 40	Great Discomfort
40 <= *humidex* < 45	Huge Discomfort (Avoid exertion)
humidex >=45	Really Dangerous (Heat Stroke possible)

And these categories define the color palette in figure 9.

Based on daily time series of daily air temperature and relative humidity resulting from JRA-55 reanalysis, we had the possibility to compare EURO-CORDEX results (the four members ensemble average) with observational values, in terms of the relative extremely rare events (99.9^{th} percentile, Figure 9): the observed picture of *"great discomfort"* conditions (orange color in figure 9) over Emilia Romagna and western Adriatic coast is well captured by the models, same as the *"some discomfort"* conditions over the eastern Adriatic coast. These are really promising results suggesting that EURO-CORDEX projections can be used to investigate also a composite index such as the humidex.

5 Precipitation based indices evaluation over the present period

Model biases typically depend on the region analyzed and are partly related to parametric uncertainty and choices in model configuration and can be affected by internal variability as well as by uncertainties of the observational reference data themselves (Kotlarski et al. 2014).

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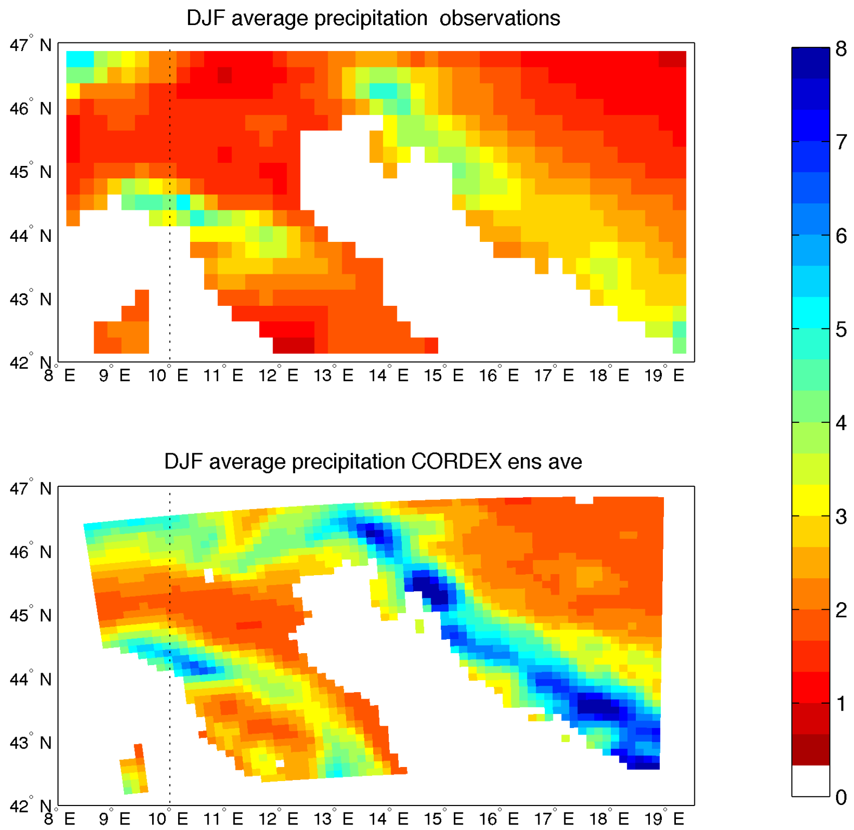

Figure 10: Winter (December to February – DJF) averaged precipitation over the 1976:2005 period. Upper panel shows observations (E-OBS) and lower panel shows the 4 members EURO-ORDEX ensemble average. Units are [mm/d].

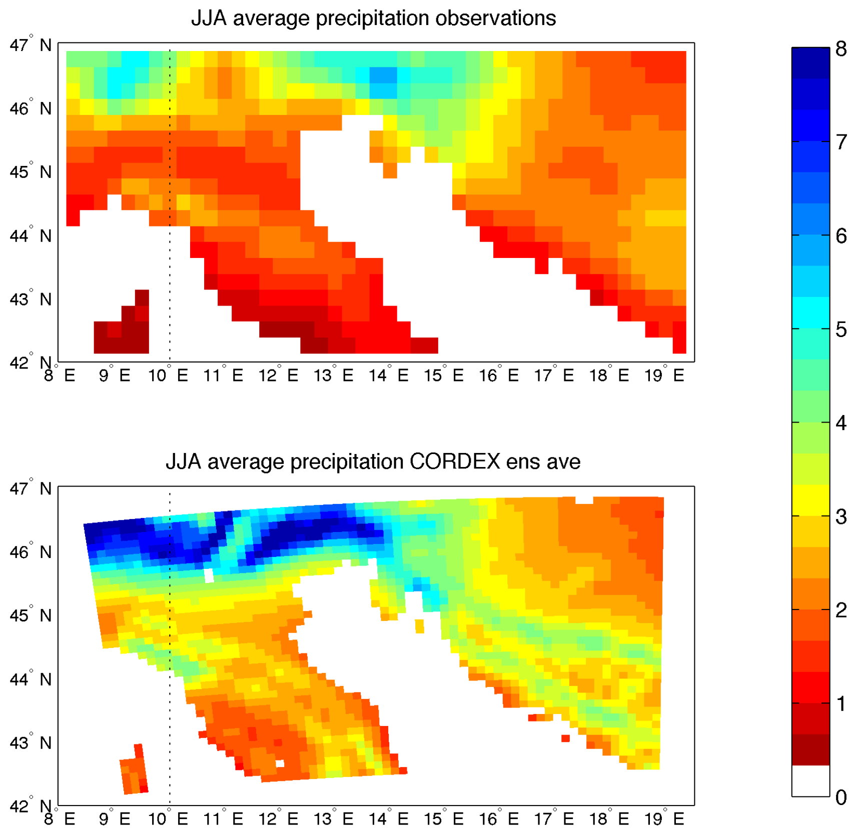

Figure 11: Summer (June to August – JJA) averaged precipitation over the 1976:2005 period. Upper panel shows observations (E-OBS) and lower panel shows the 4 members EURO-CORDEX ensemble average. Units are [mm/d].

RCMs considered in ADRIADAPT are able to reproduce the most important climatic features at regional scales, in particular temperature biases are really low (see previous section) over our region of interest. Nevertheless important biases remain, especially when focusing on precipitation. Over the ADRIADAPT domain the EURO-CORDEX models tend to overestimate over Croatia and also over the Italian case studies, more in winter than in summer (Figures 10 and 11). This tendency to an overestimation of precipitation over orographic features is common in many RCMs when moving from the 50 km (EUR-44 EURO-CORDEX grid) to the 12.5 km (EUR-11 EURO-CORDEX grid) horizontal resolution. This is reflected also in the standard deviation of the daily precipitation over the 1976-2005 period, showing a positive bias more pronounced over the mountain, but also present over Italian plains.

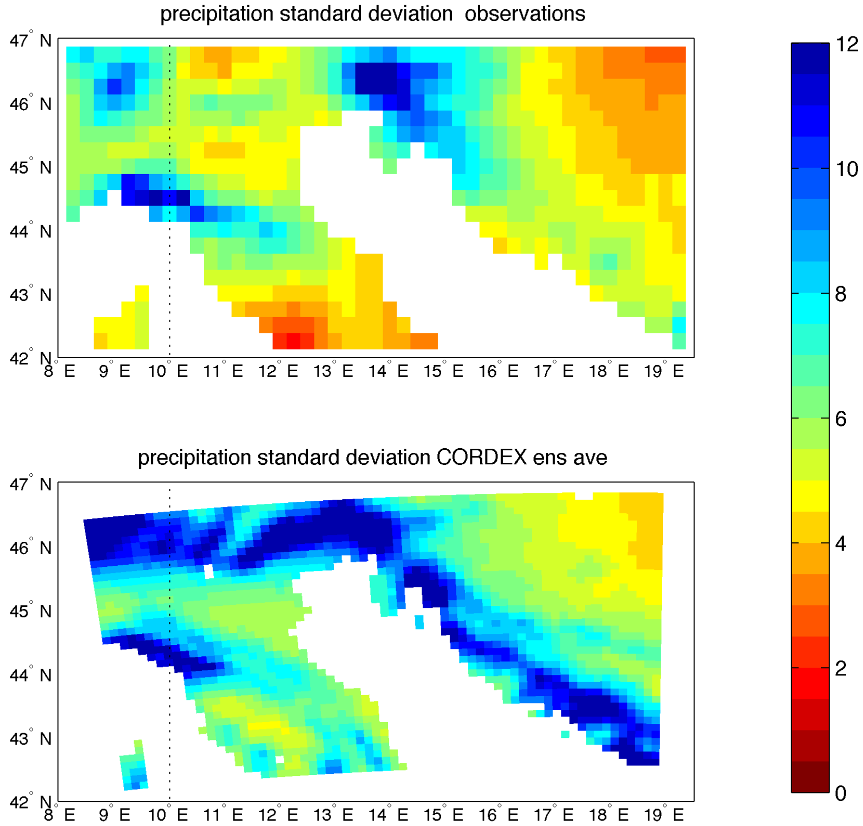

Figure 12: Standard deviation of daily precipitation over the 1976:2005 period. Upper panel shows observations (E-OBS) and lower panel shows the 4 members EURO-CORDEX ensemble average. Units are [mm/d].

Very similar biases over the orographic features are still present when focusing on extreme (99th percentile, figure 13) and intense (95th percentile, figure 14) precipitation. On the other hand, over the coastal regions of the Adriatic sea, model results are better in agreement with observations considering averages and also considering the right tail of the precipitation distribution, as suggested by the 95th and 99th percentiles.

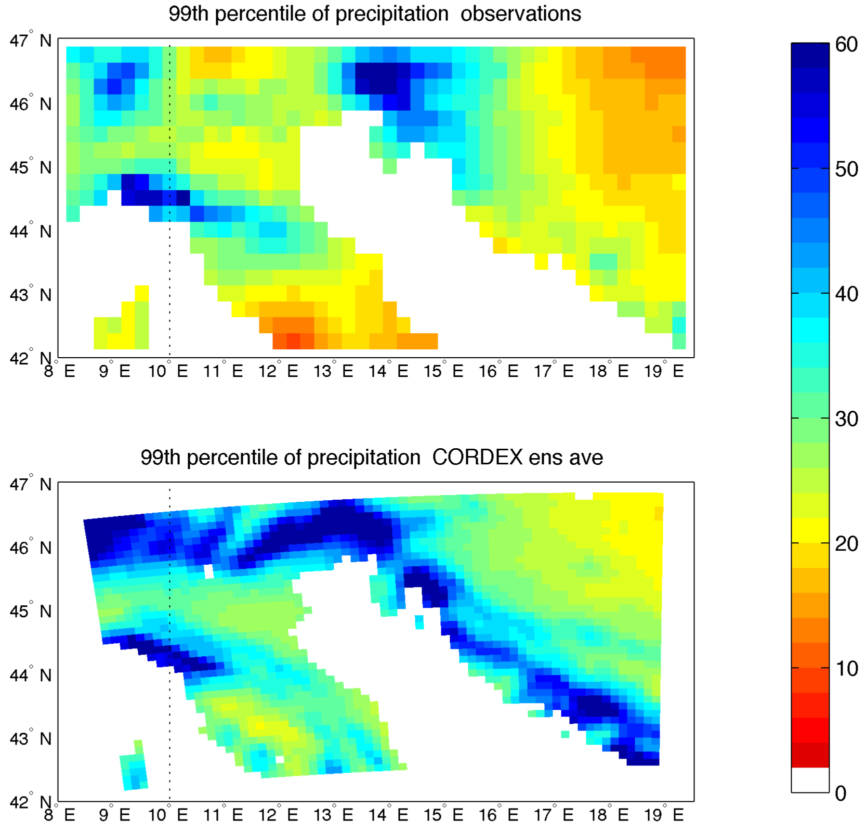

Figure 13: Extreme precipitation (99th percentile) of daily precipitation over the 1976:2005 period. Upper panel shows observations (E-OBS) and lower panel shows the 4 members EURO-CORDEX ensemble average. Units are [mm/d].

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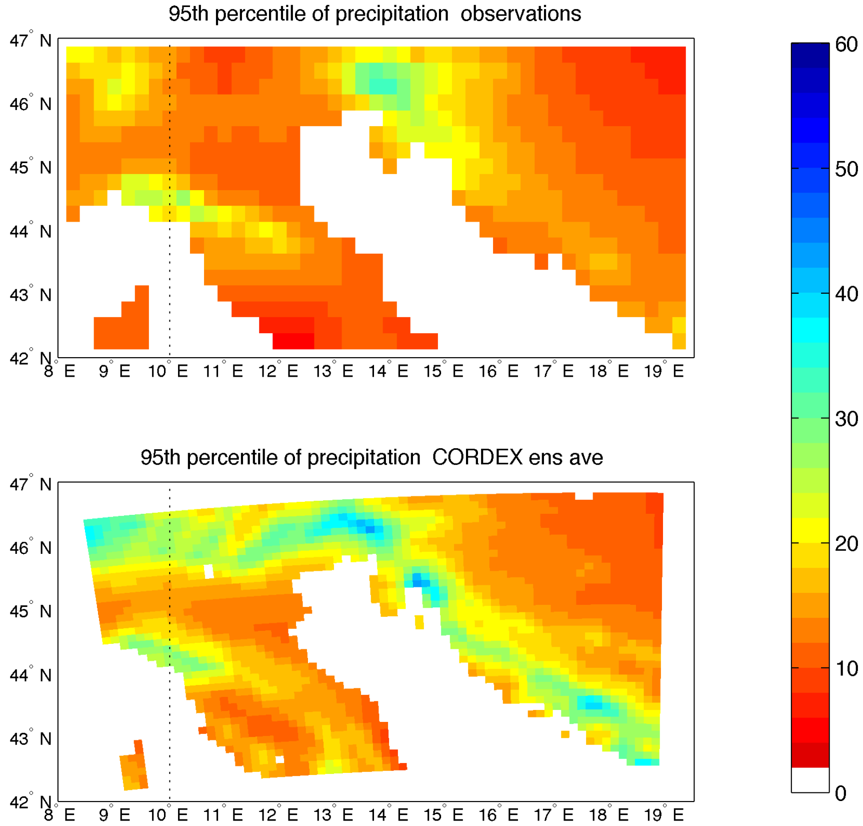

Figure 14: Intense precipitation (95th percentile) of daily precipitation over the 1976:2005 period. Upper panel shows observations (E-OBS) and lower panel shows the 4 members EURO-CORDEX ensemble average. Units are [mm/d].

6 Representation of tendencies over case studies

In order to provide an additional evaluation of EURO-CORDEX models over some case studies cities, we averaged annual values in small boxes (about 30km X 30km) as indicated in figure 1, for the municipalities of Cervia, Vodice and Zagreb (other cities, such as Šibenik and Split, can be considered for the provision of local time series). Despite we can't expect year by year correspondence between observed and modelled values because the only model time constrain is relative to the radiative forcing (greenhouse gas and aerosols concentrations), looking at time series of anomalies (with respect to the beginning of the considered historical period – i.e. 1976:1981) can help to verify if/where models are capturing the observed tendencies.
Noteworthy over all of the considered case studies, temperature tendencies are reasonably well represented (figures 15, 17, 19), with Cervia domain showing a modelled tendency a bit underestimated compared to the other cities. Also the tendencies are less pronounced inland (Zagreb) than along the Adriatic coasts (Cervia and Vodice).
In terms of precipitation no significant tendencies emerged over the period both in observations and models (figures 16, 18, 20). In addition the modelled precipitation interannual variability is reasonably in agreement with observations.

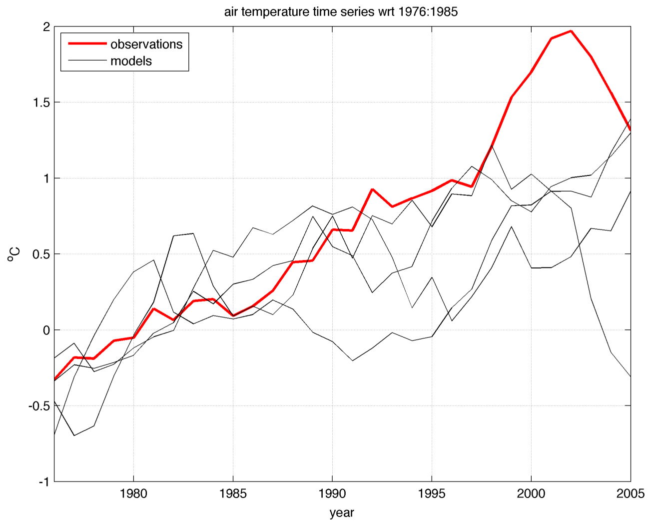

Figure 15: Annual air temperature anomaly time series (5 year running average) over CERVIA domain (see red "C" box in Figure 1). Anomalies are computed with respect to 1976:1985 period. Red line represents observations (E-OBS) while black lines show the 4 EURO-CORDEX members. Units are [°C].

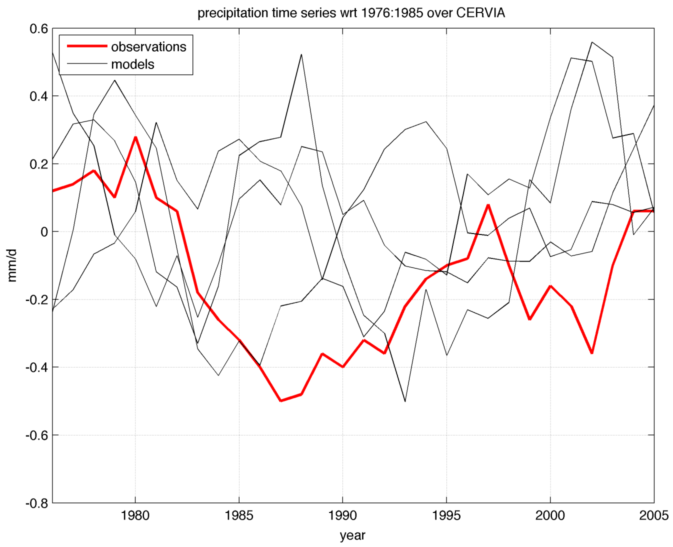

Figure 16: Annual precipitation anomaly time series (5 year running average) over CERVIA domain (see red "C" box in Figure 1). Anomalies are computed with respect to 1976:1985 period. Red line represents observations (E-OBS) while black lines show the 4 EURO-CORDEX members. Units are [mm/d].

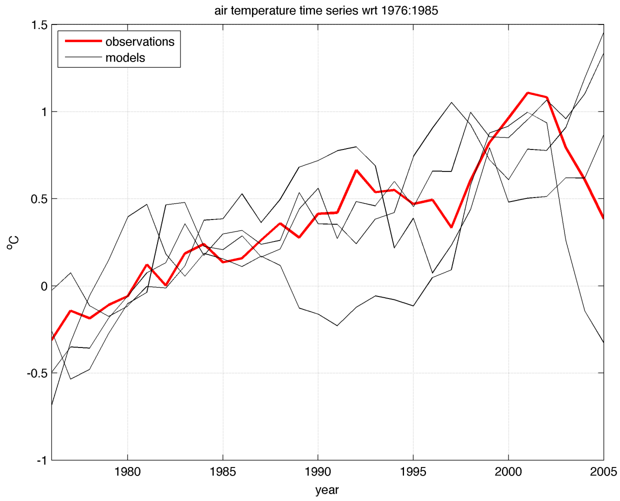

Figure 17: Annual air temperature anomaly time series (5 year running average) over VODICE domain (see red "V" box in Figure 1). Anomalies are computed with respect to 1976:1985 period. Red line represents observations (E-OBS) while black lines show the 4 CORDEX members. Units are [°C].

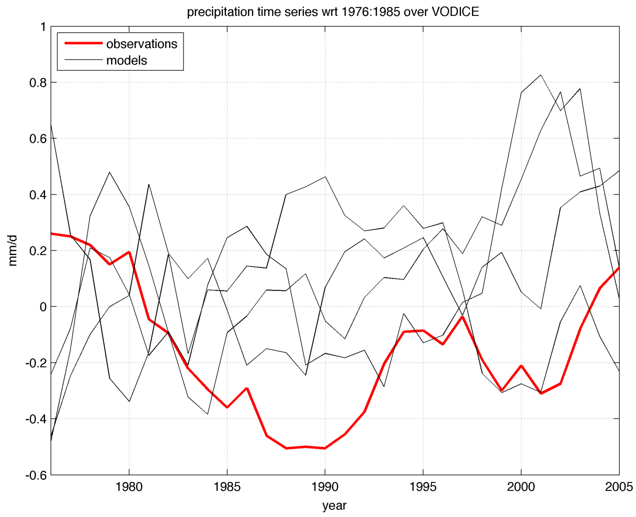

Figure 18: Annual precipitation anomaly time series (5 year running average) over VODICE domain (see red "V" box in Figure 1). Anomalies are computed with respect to 1976:1985 period. Red line represents observations (E-OBS) while black lines show the 4 EURO-CORDEX members. Units are [mm/d].

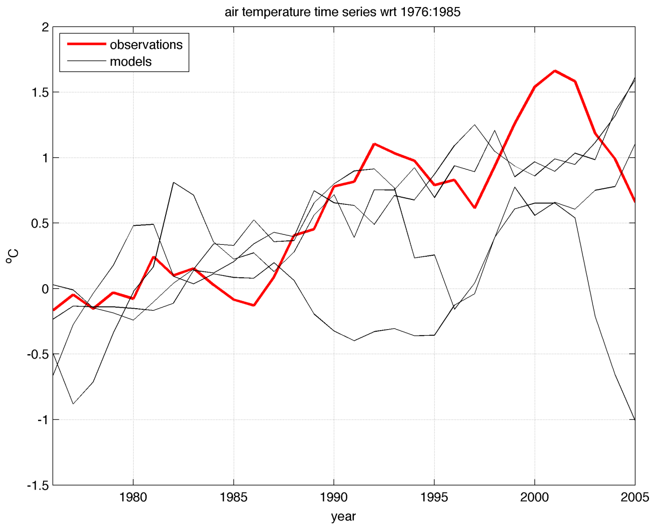

Figure 19: Annual air temperature anomaly time series (5 year running average) over ZAGREB domain (see red "Z" box in Figure 1). Anomalies are computed with respect to 1976:1985 period. Red line represent observations (E-OBS) while black lines show the 4 EURO-CORDEX members. Units are [°C].

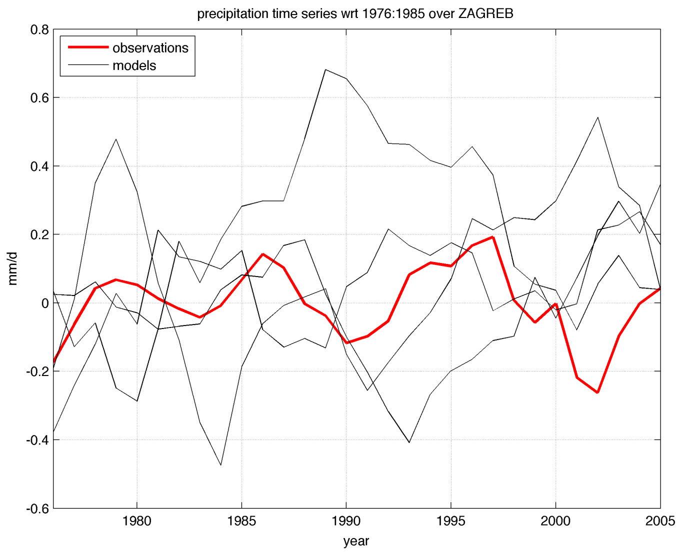

Figure 20: Annual precipitation anomaly time series (5 year running average) over ZAGREB domain (see red "Z" box in Figure 1). Anomalies are computed with respect to 1976:1985 period. Red line represent observations (E-OBS) while black lines show the 4 EURO-CORDEX members. Units are [mm/d].

https://www.italy-croatia.eu/adriadapt

7 Conclusions

In this document, after a brief description of the downscaling approaches used to collect high resolution data over the ADRIADAPT domain, we evaluate the performance of the selected Regional Climate Models in representing some of the extreme event indices defined in deliverable D3.1.1 over the historical period. Another deliverable D3.2.2 will follow with a more extended analysis considering more elaborated indices. In terms of temperature related indices there is a more robust agreement between model results and observations, compared to precipitation results, consistently with the difficulties in representing orographic features at the resolution of the models involved (about 10 km). Also in terms of tendencies over the ADRIADAPT case studies, Euro-CORDEX models well capture observed trends, suggesting that the chosen dataset, obtained through dynamical downscaling, can be used for future scenario evaluation (object of the deliverable D3.3.1).

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