LIFE SEC ADAPT PROJECT

Upgrading Sustainable Energy Communities in Mayor Adapt initiative by planning Climate Change Adaptation strategies

CLIMATE ASSESSMENT ON LOCAL AND REGIONAL LEVELS

METHODOLOGICAL DOCUMENT

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TABLE OF CONTENTS

1. Introduction

Climate change/variation has occurred in the past, present in the present time, and also foreseen in the future, with a very high intensity of change expected in the very near future – by the end of the 21st century. This brings the risks of undesired change, which makes it necessary to timely identify sensitive areas and sectors of human activities. Coastal karst regions are particularly sensitive to potential change, such as both, the Istrian peninsula and the Marche region, where because of the open character of karst aquifers potential impacts have stronger dynamics. The modern world is facing many challenges. One of the biggest challenges is endangering balance of global planetary ecosystem by increasing emissions of greenhouse gases and consequently, global warming and climate change. At the international scientific level a consensus was reached on the existence of global warming and climate change. The effects of climate changes and global warming are already being felt in the form of more frequent occurrence of extreme weather conditions in many parts of the world. Findings of the Fifth Report of the Intergovernmental Panel on Climate Change – IPCC show that climate change is in its progress and that it is necessary to take significant measures in order to mitigate effects and scope of these changes, both in terms of reducing greenhouse gas emissions, as well as in terms of adaptation to climate changes. According to the estimates made in the context of the Fifth Report of the IPCC, the expected increase in global air temperature by the end of the 21st century (2081.-2100.) in relation to the period from 1986. to 2005. year is 0.3 to 1.7 ° C for the optimistic scenario RCP2.64 (421 ppm CO2 and 475 ppm greenhouse gas), or 2.6 to 4.8 ° C for the pessimistic scenario RCP8.5 (936 ppm CO2 and 1,313 ppm greenhouse gases). Expected sea level rise / ocean is 26-82 cm to the period 2081.-2100 year, depending on the observed scenario. Also in the Fifth report it is argued, with high confidence (over 95%) that the man affected the climate and increasing global temperature since 1950. To address this, the Life SEC Adapt project is implemented in a significant number of locations in the Istria region (6 locations) in Croatia and the Marche region (12 locations) in Italy. The planned pilot areas in Istria are the towns of Buzet, Labin, Pazin, Poreč, Pula and Rovinj with Italian Municipalities Ancona, Pesaro, Urbino, Senigallia, Jesi, Fabriano, Macerata, Fermo, Ascoli Piceno, Offida, San Paolo di Jesi, and Santa Maria Nuova.

Even though there are considerable differences in assessment whether the above-mentioned imminent climate change can be attributed to global climate change or only to climate variation, the projections done so far and manifestations of such potential change suggest that when managing water and other resources it is necessary to take account of potential continuation and even increase of negative trends of climate change regardless of whether this is irreversible change or common climate variation. Contemporary approaches to managing water and other resources require the preparation of different scenarios of potential long-term change in order to timely identify the risks and prepare and optimize protective management measures. In April 2013, the European Commission adopted the EU Strategy on adaptation to climate change to encourage the Member States, particularly those that still don't have national strategies, prepare their national strategies and update these in the future. A CLIMATE-ADAPT platform has been established, providing access to databases and exchange of data and information about expected climate change in Europe, as well as about strategies and possible adaptation options to potential change (http://climate-adapt.eea.europa.eu/).

Different scenarios for assessment of climate change impacts exist, so the methods of slowing down the undesired processes as well as of adapting to such change are considered.

Based on a Decision of Croatian Parliament on Ratification (OG 55/1996), Croatia has assumed obligations of the 1996 United Nations Framework Convention on Climate Change (UNFCCC) and prepared the First National Communication of the Republic of Croatia to the UNFCCC (Ministry of Environmental Protection and Physical Planning, 2001). The Sixth National Communication of the Republic of Croatia to the UNFCCC (Croatian Meteorological and Hydrological Service, 2013) is currently relevant, and in mid-May 2016 the Ministry of Environmental and Nature Protection is starting implementation of the project "Building the capacities of the Ministry of Environmental and Nature Protection for climate change adaptation and preparation of the Draft Climate Change Adaptation Strategy", which is expected to be completed in late 2017. A special attention is given to the water and energy sectors, agriculture, forestry, fisheries and protection of biodiversity, and the associated health, tourism and economy sectors as the sectors with risks of potentially heaviest consequences of undesired climate change.

Concerning Italian context, on June 16 2015 the Ministry of the Environment formally approved the National Strategy on Adaptation to Climate Change (http://www.minambiente.it/sites/default/files/archivio/allegati/clima/strategia_adattamentoCC.pdf) .

The strategy responds to the broader goals set out in the adaptation strategy package adopted by the European Commission in April 2013, with the aim of making Europe better prepared to withstand existing and future climate impacts.

The Italian strategy sets out principles and measures with the aim of:

- reducing risks that arise from climate change;
- protecting public health;
- preserving natural heritage;
- maintaining and strengthening the resilience and adaptation capacity of natural, economic and social systems;
- taking advantage of potential benefits that new climatic conditions may create.

It also describes the impacts of climate change on nature, economy and society and indicates sectors as priority following the results of the impacts and vulnerabilities assessment:

- water resources and areas prone to desertification risk;
- soil erosion and coastal zone flooding;
- loss of biodiversity;
- modification of marine and mountain ecosystems;
- loss of snow and glaciers covered areas;
- negative impacts on health and wellness;
- increase of hydrogeological risk;
- Po river basin and the river district of Central Appennines where are situated the main water reservoirs.

Furthermore the Italian strategy gives, for all sectors considered, a set of actions, classified in soft, green , grey, medium-long term and intersectoral in order to mitigate impacts of climate change.

On the regional spatial-temporal scale, in addition to general trends of change of characteristic indicators of climate and the related hydrological conditions, the status of resources (water, soil, plants and animals) is under a strong impact of local human pressures associated with different technical solutions and different forms of water use at present and in particular in the future. This particularly refers to projects which modify the boundary conditions of run-off and to projects associated with water use, primarily for irrigation and water supply. Even though irrigation in terms of existence of large organized irrigation systems is for the time being relatively poorly present in Istria, the growth of individual intakes of water for irrigation from coastal aquifers, particularly on Istria's western and southern coast, indicates possible more serious problems in the future with deeper intrusion of seawater into the coastal karst aquifers due to their abstraction. On the other hand, it is precisely because of the expected climate change that the Mediterranean has been identified as the region where the development of irrigation is essential. The same problems are also present in Marche region (with reference to coastal alluvial aquifer).

For that reason, there is a real concern that the negative processes of seawater intruding into the coastal aquifers could expand and intensify even more in the future, in particular if the planned irrigation development plan adopted by Istrian County comes true, with annual water demand in phase I expressed as 10-15 million m3, and as much as 52 million m3 in phase II (https://www.istra-istria.hr/uploads/media/Sazetak_novelacije.pdf), which is several times than app. 20 million m3 of water currently used for water supply.

Under expected conditions of climate change, a compromise will have to be reached between increasing demand for irrigation water, without which adequate agricultural production to satisfy the need for food won't be possible, and the need to protect water resources and the associated aquatic ecosystems from excessive exploitation of water for irrigation needs.

Climate modelling of potential change using regional climate models

2. Current climate trends

As outlined by the Fifth IPCC Assessment Report (Hartmann et al., 2013), climate change impacts are already evident in many geographical areas of the world, and the Mediterranean region is considered a hot spot of climate change (Diffenbaugh et al., 2007; Giorgi, 2006). 8 These impacts influence many important socio-economic and production sectors as energy, transports, agriculture and tourism, as well as natural environment resources, including mountainous areas and forests, ecosystems and biodiversity, water resources, coastal areas and marine environment. And, last but not least, the health of the population.

The implementation and evaluation of the potential adaptation strategies depends on the accurate knowledge of the climate characteristics, their variations and the impacts related to specific features and vulnerabilities of the territory. In addition, it is fundamental that the most important elements of knowledge, along with the awareness of the uncertainties of the impact estimates, are continuously updated and clearly communicated to stakeholders.

The primary source of information about the climate and its variations on a specific geographical area is represented by the reconstruction of recent past climate (typically, the last decades) and the recognition and estimate of climate trends of both mean and extreme values. Current climate tendencies may be eventually responsible of impact signals on the territory, already recognizable or estimated in rapid evolution.

This information is provided by the analysis of time series of meteorological observations representative of the locations under investigation, and by the application of statistical models for trend recognition and estimation. Instrumental climate time series are also necessary for the assessment of climate models' skills and consequently for tuning the adaptation strategies.

The capabilities of medium and long term climate projections are based on dynamical climate models. Atmosphere-Ocean General Circulation Models (AOGCMs), based on well established physical laws, reproduce the average characteristics of past and recent climate, at the horizontal resolution of 250-600 km (Olsson et al., 2013) and are the best tool to assess future climate evolution. However, at the regional scale, climate is strongly influenced by local factors (as the regional topography) that are coarsely represented by AOGCMs; moreover, the AOGCM simulations do not include several physical processes, occurring at a finer scale than model resolution (Ehret et al., 2012). Regional Climate Models (RCMs) give more reliable simulations at the regional and local scale, due to their higher resolution (10-50 Km) and a more complete representation of physical processes. They are nested into a global model, which provides the forcing at the boundaries, and produce climatic projections over the domain of interest.

2.1 Data quality control and selection of data series

The recognition and estimate of the trends of climate variables are carried out through the statistical elaboration of time series originating from meteorological monitoring stations. The series must be as long as possible (at least 50-60 years), quality checked, complete and continuous in time.

Careful analysis of data quality is an essential activity before undertaking any long-term climate change analysis. Data values can be erroneous for a variety of reasons (i.e. values may be repeated for a period of days, duplicated for months or years, inconsistent with other elements, physically impossible or climatologically implausible).

As recommended by WMO (2011), data quality controls should be performed in semiautomatic fashion. When validating a large quantities of data it is essential to elaborate automatic control procedures, which examine all the available data and list those that fail predefined tests. However, a manual review of the automated outputs is needed, in order to validate potential errors and determine any corrections that should be applied.

A comprehensive set of quality assurance (QA) procedures was implemented in Global Historical Climatology Network (GHNC)-daily QA system (Durre et al, 2010). It includes fully automatic checks for several types of data errors, grouped into five general categories: i) basic integrity checks, which identify cases of data duplication as well as physically implausible values; ii) outliers checks, which identify excessive gaps in the distributions of data values as well as observations that deviate excessively from station-specific climatological parameters; iii) internal and temporal consistency checks, which respectively test for violations of logical or physical relationships between two or more elements and identify values that deviate significantly from ''adjacent'' observations in time; iv) spatial consistency checks, which identify values that deviate significantly from ''adjacent'' observations in space; v) megaconsistency checks, which verify the integrity of all remaining unflagged observations.

A subset of these controls was developed in ISPRA and applied to the Italian dataset of daily temperature and precipitation series (Fioravanti et al., 2016 available on ISPRA web-site). This implementation required to fix new test thresholds, adjusted on Italian climate features. The whole quality control process consists of a sequence of several automated controls, which identify and flag erroneous values, setting them to missing values. A manual review of the automated outputs was also performed for some kinds of tests (i.e. spatial controls).

With reference to completeness and continuity of temporal series, WMO (2011) points out that missing values are much more critical for some climatic elements than for others. Total monthly precipitation amounts may be strongly compromised by a few days of missing data, while monthly averaged temperature may be less influenced. Strict completeness criteria are needed to calculate extreme temperature and precipitation indices, because some analyses are critically dependent on the completeness of the data (Klein Tank et al., 2009).

The following criteria are required to calculate extreme indices: 1) at most 3 missing days in a month and 2) no more than 15 missing days in a year, having all monthly values available (Vincent et al., 2005; Donat et al., 2014).

The last stage of the series selection process consists in checking the serial completeness and continuity of time series (over the entire analysis period).

A frequently used criterion consists in selecting only time series at least 75-80% complete (Alexander et al., 2006; Klein Tank and Können, 2003; Toreti and Desiato, 2008a), with a maximum of four consecutive missing values (Desiato et al., 2102; Fioravanti et al., 2015).

In order to get reliable trends estimates, it is also necessary to leak from the series eventual non-climatic signals, like those due to station relocation or change of meteorological instrumentation.

At this purpose, station metadata provide researchers relevant information for the detection of artificial discontinuities (breakpoints) and their causes (Peterson et al., 1998). However, when no or very limited metadata accompany data records, homogeneity assessment relies only on statistical techniques. Data series undergo a number of suitable homogeneity statistical procedures and are homogenised whenever one or more break points are found (e.g. Kuglitsch et al., 2009; Aguilar et al., 2003). Generally, absolute tests, which checks the self-consistency of each candidate series, are considered less effective than relative tests, which checks the homogeneity of any candidate time series against a corresponding reference series, highly correlated with the candidate series (e.g. Peterson et al. 1998, Venema et al. 2012).

The most common approach for creating a reference series is to calculate a weighted average of data from neighboring stations, for each candidate series. Following to the guidance of Peterson and Easterling (1994) the most adequate neighboring series are selected according to their correlation with the candidate series, where correlation coefficients are calculated between the first-differenced time series (FDi = Ti+1 – Ti, for year i). When the reference series is constructed, squared correlation coefficients (positive) are used as weighting factors (see also Desiato et al., 2012).

Most of papers concerns the homogenization of temperature time series, since they are characterized by a lower variability compared to precipitation ones and are more sensitive to inhomogeneities. To detect multiple change-points (shifts) that could affect data series, several authors used the two phase regression test, implemented in the RHtest software package (http://etccdi.pacificclimate.org/software.shtml). It is based on the penalised maximal t-test (Wang et al. 2007) and the penalised maximal F-test (Wang 2008a), which are embedded in a recursive testing algorithm (Wang 2008b). Figure 1 illustrates an example of breakpoint detection in the annual average temperature series of the station of Ciampino (candidate series), using the RHtest. Three possible inhomogenities were identified in 1965, 1972 and 1977.

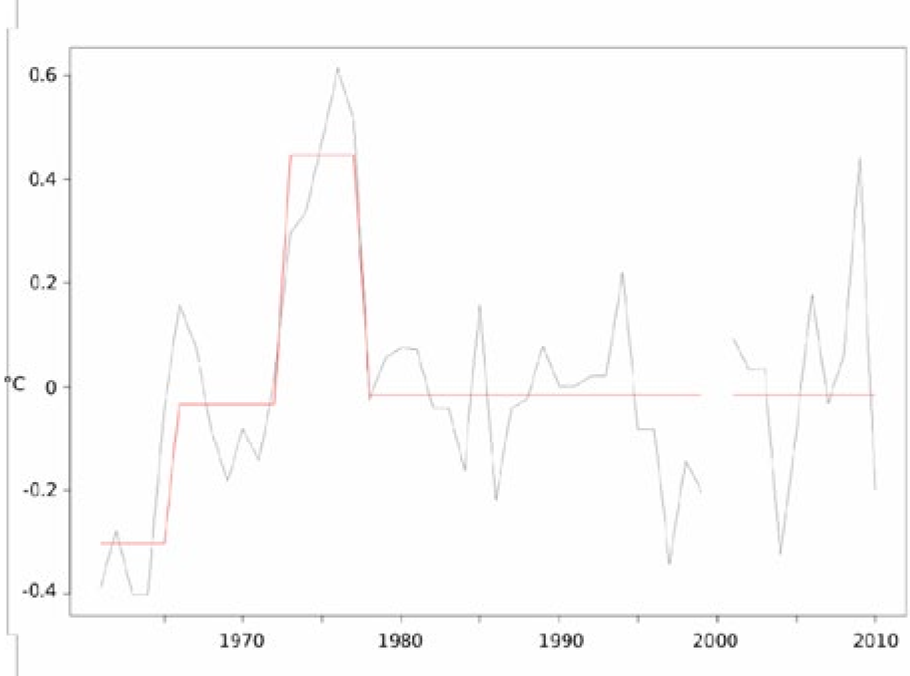

Figure 1 – Example of breakpoint in the annual average temperature series for the station of Ciampino (anomalies relative to a reference series computed from surrounding stations). Three inhomogeneity are detected in 1965, 1972, 1977, using RHtest (Desiato et al., 2012).

Regarding to daily resolution time series, detecting inhomogeneities and adjusting climatological data sets is a difficult issue; generally it requires a dense network of stations for the definition of highly correlated reference series (Della Marta and Wanner 2006; Kuglitsch et al. 2009; Toreti et al. 2010). In the WMO guidelines on the analysis of extremes (KleinTank et al., 2009) the suggestion is to remove time series with indications of artificial changes from the extremes analysis altogether and use only homogeneous series, if the available number of records and the station density allow it. In a previous analysis of recent changes of temperature extremes over Italy (Fioravanti et al., 2015) a breakpoint detection procedure was undertaken, in order to discard the inhomogeneous series and select only the homogeneous ones. The homogeneity testing was carried out at the annual level, with the objective of identifying the potential major problems. This approach does not secure the results from all kinds of discontinuities; nonetheless, running the homogeneity assessment at the annual level prevent from accepting records whose annual series show gross discontinuities which may affect the respective daily series.

Each annual maximum and minimum temperature time series was tested using the penalized t-Test (RHtestV3) and homogeneous series were identified, according to the following procedure. Series with statistically significant breakpoints were immediately excluded from the analysis. On the contrary, series with non-significant breakpoints were re-processed according to the iterative procedure described by Wang and Feng (2010). That is, at each step the smallest non-significant breakpoint was ignored and the remaining breakpoints were re-assessed. If this new assessment generated statistically significant breakpoints the iterative process was terminated and the series discarded. If non-significant breakpoints were still detected, the procedure was newly repeated according to the above-said scheme, with a maximum number of three iterations.

As a general result of the homogeneity assessment procedure, it is likely that some minor breakpoints remained undetected in the daily series. However, such inhomogeneities should be sufficiently small to hardly affect the results in terms of trends and variability.

2.2 Indices calculation

The assessment of climate change impacts requires updated estimates of the tendencies of both the mean and the extreme values of temperature and precipitation.

In order to describe the variability of climate extremes, the ETCCDI core set of indices (http://etccdi.pacificclimate.org/list_27_indices.shtml), defined by the Commission for Climatology/Climate Variability and Predictability (CCl/CLIVAR) Working Group on Climate Change Detection (Peterson et al., 2001) was used in several studies (Alexander et al., 2006; Toreti and Desiato, 2008b; Donat et al., 2013).

With the objective of studying recent variations in frequency and intensity of temperature and precipitation extremes over Italy, a subset of ETCCDI indices was selected and analysed in previous researches (Desiato et al., 2013; Fioravanti et al., 2015). They are reported in tables 1 and 2, respectively for temperature and precipitation. With reference to temperature, an additional index is included in table 1, the "hot days" number (SU30), significant for Mediterranean climate. It was selected from the ET SCI core set of 34 indices, relevant for health, water and agriculture sectors, defined by the WMO Commission for Climatology (CCl) Expert Team on Sector-specific Climate Indices (ET SCI,). http://www.wmo.int/pages/prog/wcp/ccl/opace/opace4/ET-SCI-4-1.php

Temperature

Index	Definition	Units
FD0 (Frost Days)	Annual count of days when TN (daily minimum) < 0°C	days
SU25 (Summer days)	Annual count of days when TX (daily maximum) > 25°C	days
TR20 (Tropical nights)	Annual count of days when TN (daily minimum) > 20°C	days
TN10P (Cold nights)	Percentage of days when TN<10th percentile of the base period	%
TN90P (Warm nights)	Percentage of days when TN>90th percentile of the base period	%
TX10P (Cold days)	Percentage of days when TX<10th percentile of the base period	%
TX90P (Warm days)	Percentage of days when TN>90th percentile of the base period	%
WSDI (Warm Spell Duration Index)	Annual count of days with at least 6 consecutive days when TX > 90th percentile of the base period	days
SU30* (Hot days)	Annual count when TX ≥ 30°C	days

Table 1 – Extreme temperature indices selected from ETCDDI and ET SCI (*) core sets, where TN = minimum temperature and TX = maximum temperature

Precipitation

Index	Definition	Units
RX1day (Max 1-day precipitation amount)	Maximum value of 1-day precipitation	mm
R95p (Very wet days)	Annual total precipitation when daily PRCP > 95th percentile of the base period	mm
SDII (Simple Daily Intensity Index)	Annual total precipitation divided by the number of wet days (defined as daily PRCP ≥ 1.0 mm) in the year	mm/day
CDD (Consecutive Dry Days)	Maximum number of consecutive days with daily PRCP <1mm	days
R20 (Very heavy precipitation days)	Annual count of days when daily PRCP ≥ 20 mm	days

Table 2 – Extreme precipitation indices selected from ETCDDI core set

2.3 Trend calculation

The variation of climatic variables, in terms of differences or, as in the case of precipitation, percentage differences in the unit of time (year or century), are estimated through the application of statistical models for trend recognition and linear and non-linear statistical models for trends estimate (e.g. Seidel and Lanzante, 2004; Tomé and Miranda, 2004).

Trend analysis of climatic variables are usually performed in a non-parametric fashion using the Mann–Kendall rank test (Mann 1945; Kendall 1976) and the Theil–Sen estimator (Sen 1968), which is a more robust approach for the estimation of trends than the least squares estimator. The confidence interval for the slope may be calculated using the method defined in Sen (1968).

When climate data series are affected by persistence (autocorrelation), Mann-Kendall test tends to reject the null hypothesys (randomness hypothesis) more often than evaluated by the significance level (von Storch, 1995). A common approach to tackle this issue consists in removing the autocorrelation component from the data (pre-whitening), assuming a first-order (AR1) autoregressive process as a good approximation. According to the iterative procedure of Wang and Swail (2001), the autocorrelation component is initially removed from the series and its trend calculated. This estimate is then removed from the original series and autocorrelation is recalculated. This process continues until the differences in the estimates of the slope and the AR(1) component are negligible in two consecutive iterations. When this happens, the Mann-Kendall test is run on the resulting time series and the Theil-Sen estimator is calculated.

Figure 2 shows an example of trend analysis of percentage precipitation anomalies in Italy from 1951 to 2010 (Desiato et al., 2012), using both a simple regression model and the Theil–Sen estimator. The simple regression model show a non-significant negative trend of -0.155%/year for northern Italy, a significant negative trend of a -0.289%/year for the Centre (-17 % from 1951 to 2010), a significant negative trend of -0.230%/year for the South (-13.6% from 1951 to 2010). The Theil-Sen estimator and Mann-Kendall test confirm these results, showing a negative trend of -0.179%/year for northern Italy, -0.290%/

year for the Centre and a -0.270%/year for the South. The Mann-Kendall test highlights that trends are significant only for central and southern Italy.

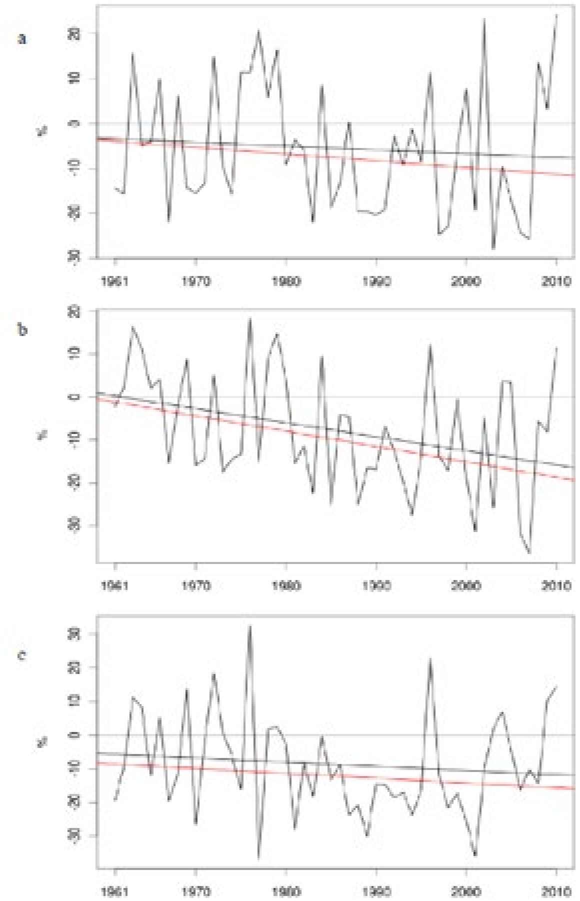

Figure 3 – Percentage a [illegible] ean value) and relative trends, for northern (a), central (b) and southern Italy(c). Trends are estimated using the simple linear regression (black line) and Theil-Sen estimator (red line).

3. Future climate projections

GCM projections refer to different emission scenarios, representing different models of greenhouse gases evolution until the end of the 21th century and corresponding to different hypothesis for the global socio-economical development. A set of four scenarios, known as Representative Concentration Pathways (RCPs) has been developed for the climate community as a basis for long-term and near-term modelling experiments. These RCPs complement and, for some purposes, replace earlier scenario-based projections of atmospheric composition (Meinshausen et al., 2011), such as those from the IPCC Special Report on Emissions Scenarios (IPCC, 2000).

The RCPs, produced by an innovative collaboration between integrated assessment modelers, climate modelers, terrestrial ecosystem modelers and emission inventory experts, cover the 1850-2100 period and extensions have been formulated for the period thereafter. They include one mitigation scenario leading to a very low forcing level (RCP2.6), two medium stabilization scenarios (RCP4.5/RCP6) and one very high baseline emission scenarios (RCP8.5) (Van Vuuren et al., 2011). Therefore, an ensemble of predictions of climate variables in different scenarios can be obtained from numerical models. For each climatic variable there is a range (that can be considerably large) of predicted values at a certain time, including the intrinsic model uncertainties, the spectrum of values predicted by different models and the spectrum of values corresponding to different scenarios.

The RCPs are used to drive climate model simulations of Med-CORDEX initiative (www.medcordex.it), proposed by the Mediterranean climate research community as a follow-up of previous and existing initiatives. From the ensemble of Med-CORDEX simulations, daily temperature (maximum, minimum and average) and precipitation projections of four RCMs models will be selected to summarize the knowledge and the uncertainties about future climate in the target areas. These models guarantee temporal coverage from 1971 to 2100, under RCP4.5 and RCP8.5 emission scenarios. The spatial resolution of each model is roughly 50 x 50 km (0.44° on a rotated grid). Each RCM is driven by a GCM, providing the required lateral boundary conditions (table 3). GCM-driven hindcast simulations (1971-2000) will be

used as base period to evaluate climate variations. Daily data covering the domain of interest will be extracted from RCM outputs; both the mean and the extreme projected values of temperature and precipitation will be calculated and analysed (using ETCCDI indices listed in tables 1 and 2).

Future climate changes will be evaluated as differences between the projected value of a climatic variable or index and its corresponding mean in the reference period 1971-2000; it will allow to compare climatic signals from different models, independently by their ability to reproduce absolute values. Variations of mean values and extreme indices will be estimated for three future projection periods: 2021-2050, 2041-2070, 2061-2090.

Acronym	Institute	RCM	GCM
ALA-DIN	Centre National de Recherches Météorologiques	CNRM-ALADIN5.2	CNRM-CM5
GUF	Goethe University Frankfurt	GUF-CCLM4-8-18	MPI-ESM-LR
CMCC	Centro EuroMediterraneo sui Cambiamenti Climatici	CMCC-CCLM4-8-19	CMCC-CM
LMD	Laboratoire de Météorologie Dynamique	LMD-LMDZ4-NEMOMED8	IPSL-CM5A-MR

Table 1 - RCM selected from Med-CORDEX initiative

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