Key Climate Change Issues in the ClimaSouth region

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REMHI - Regional Models and geo-Hydrological Impacts

•The main activities of REMHI Division include studies about regionalization of the climatic signal through the development and use of statistical and dynamical downscaling approaches, qualitative and quantitative evaluation of the effects of climate changes on the geo-hydrological hazards (such as landslides, floods and droughts).

• The Division develops procedures able to optimize the link between climate and impacts models, and tools for the correct quantification of the associated uncertainty.

•Research units:

- REgional Models (REM)
- geo-Hydrological Impacts (HI)
- Coupling Climate with Impact models (CCI)

Involvement in ClimaSouth project

- 1st Training Workshop on Downscaling Climate Modelling Lecce, March, 9-20, 2015
- 2nd Workshop on Downscaling Climate Modelling Lecce, November, 2-6, 2015

Main aims:

- To advance capacity in Downscaling Climate Modelling for the purpose of high resolution climate impact assessment in support of adaptation actions.
- To consolidate the concepts of downscaling and high-resolution impact assessment.

Outlook

- The ClimaSouth area: climate features and expected climate changes
- Climate data (use, limitations, uncertainties…)
- Global models and Regional models: the importance of downscaling
- Analysis of existing data for the ClimaSouth area
- Data accessibility

ClimaSouth

Project funded by the European Union
Euro South Mediterranean Initiative
Climate Resilient Societies
supported by Low Carbon Economies

The ClimaSouth project supports climate change mitigation and adaptation in 9 South Mediterranean countries: Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine and Tunisia.

Introduction

- The ClimaSouth domain is located in a transition zone between the arid climates of the Saharan North Africa / Middle East and the temperate climate of central Europe.

- It is affected by interactions between mid-latitude and tropical processes.

- It is very sensitive to climate changes induced by increases of GHG concentrations.

- Anticipating climate change in the region is further complicated by the existence of a major enclosed sea (Mediterranean) with a very active regional thermohaline circulation, and linkage to the Atlantic Ocean by the Gibraltar strait.

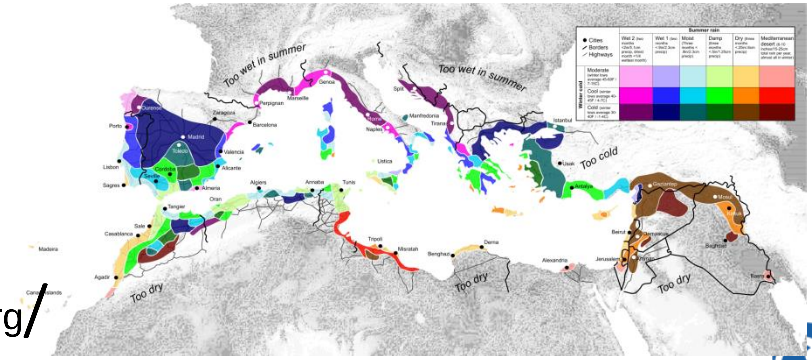
- Temperature increases combined with substantial decreases in precipitation are projected. This results in higher evapotranspiration demand and will severely stress the water resources.

Geographical aspects

- Mediterranean is roughly defined as the area between 28N – 48N and 10W – 39E.
- It extends from the Alpine region (in the north) to the north African countries (in the south).
- From the Iberian Peninsula in the west to the Middle East countries in the east.
- Many small-size islands limit the low-level air flow, and the coastline is particularly complex.
- A submarine ridge between the island of Sicily and the African coast with a sill depth of about 365 meters divides the Mediterranean Sea into western and eastern parts.
- The Mediterranean area has been identified as an “Hot Spot” for future climate change.

Features of Mediterranean climate

- Mild and wet during the winter and hot and dry during the summer.
- Winter climate dominated by the westward movement of storms originating over the Atlantic.
- Precipitation is affected by the North Atlantic Oscillation (NAO) over the western part and by the East Atlantic (EA) over the northern and western part.
- Mediterranean and North Africa are also affected by the ENSO (El Nino Southern Oscillation), causing wetter and milder winters.
- Mediterranean storms are also produced internally in correspondence of cyclogenetic areas, such as Alps, Gulf of Lyon, Gulf of Genoa.



http://www.pacificbulbsociety.org/

Features of Mediterranean climate

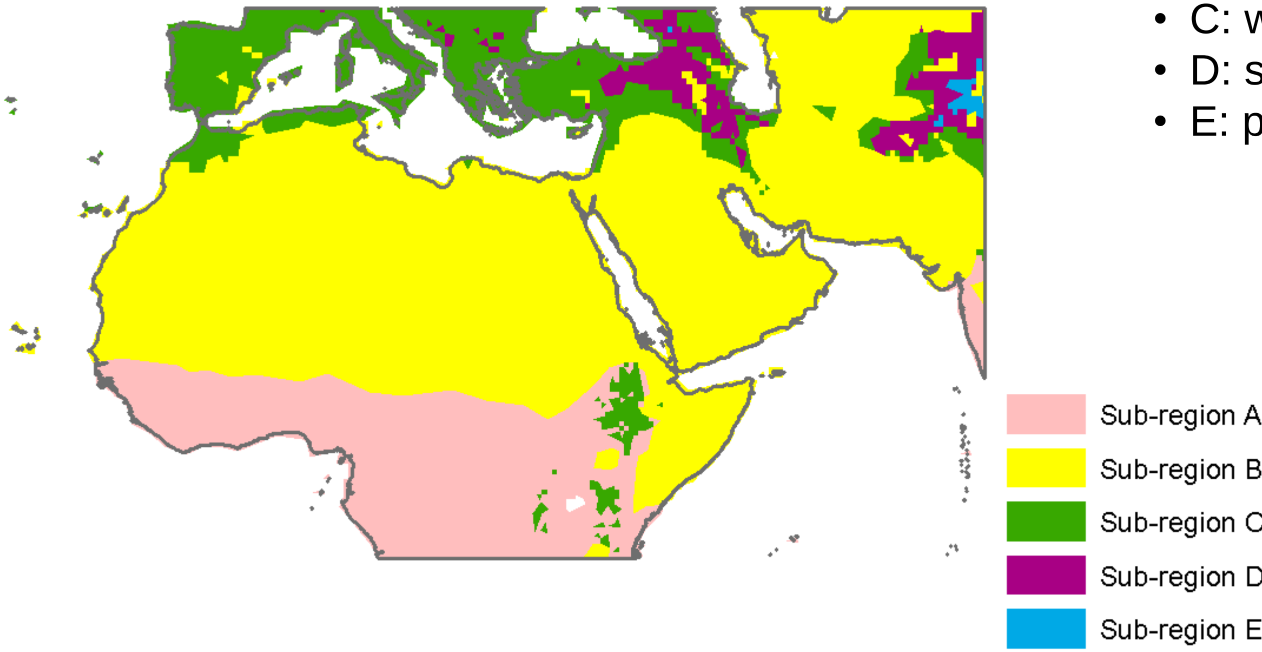
- Mediterranean area is dominated by high pressure in summer, leading to dry conditions over the southern part.
- Climate variability is also connected with African and Asian monsoon.
- Climate affected by local processes, induced by complex topography.
- Regional climate modulated by the vegetation and by the coastline.
- Natural and anthropogenic aerosols have also influence on the climatic features.

Mediterranean climate is characterized by a great space variability and a great diversity of features.

Climatic features of Middle East North Africa (MENA) domain

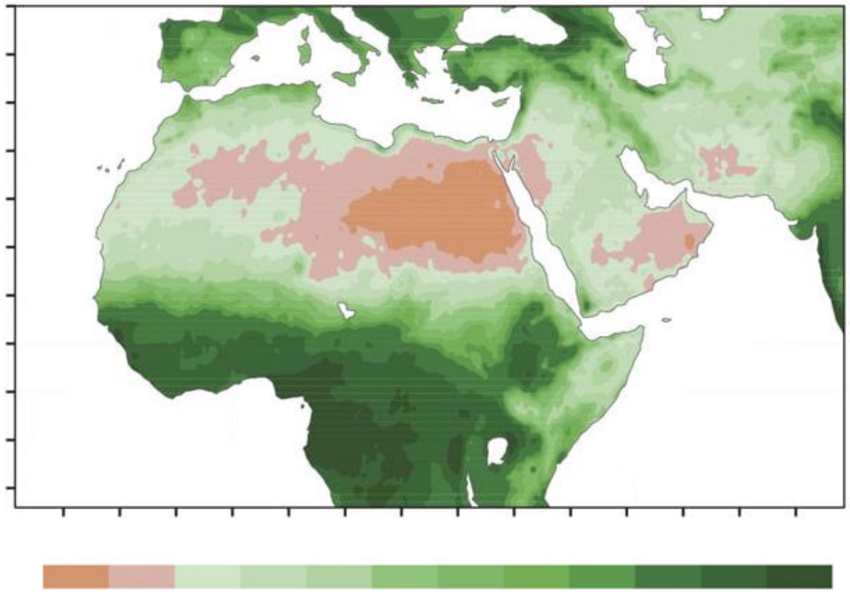
7S – 45N and 27W – 76E

- A: equatorial
- B: arid
- C: warm temperate
- D: snow
- E: polar climate



Koppen-Geiger climate classification

Climatic features of the MENA domain

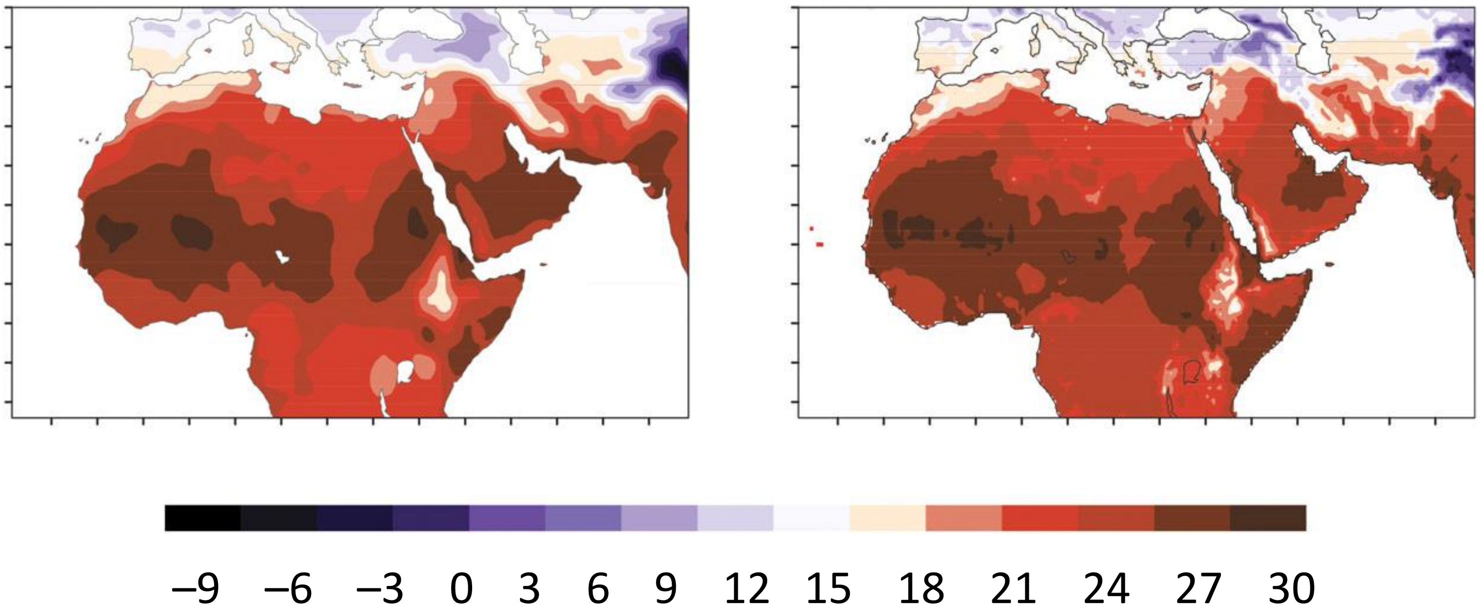


Annual rainfall averaged over the period 2001–2005 from TRMM

The three phases of the West African Monsoon (WAM):

- the pre-onset stage (March to May),
- an abrupt shift of the major rain zone i.e. the WAM onset (late June, early July),
- the southward retreat of the monsoon rain band (from September on) with a consequent rainfall reduction over Sahel.

Climatic features of the MENA domain



Daily temperature averaged over the period 2001–2005 for (left) ERA-Interim and (right) CRU data.

Saharan Heat Low* (SHL) is a major dynamical element of the WAM system. In fact, WAM is driven by the latitudinal thermal gradient between the cold sea surface temperature in the Gulf of Guinea and the high surface temperature in SHL.

* A near-surface thermal low pressure system

Climate change in Mediterranean area

- decreasing yearly cumulated rainfall values (with respect to 1961-1980):

	2001-2020	*2081-2100*
summer	-7%	-28%
fall	-3%	-15%
spring	-2%	-14%
winter	-2%	-8%

- increasing surface warming (with respect to 1961-1980):

	2001-2020	*2081-2100*
summer	+0.7°C	+4.6°C
winter	+0.7°C	+3.1°C

- increasing variability: heavier rainfall events separated by longer dry periods.

F. Giorgi, P. Lionello, Climate change projections for the Mediterranean region, Global and Planetary Change 63 (2008) 90–104

Examples of impacts of climate change on economy

• The climate change impact on Gross Domestic Product (GDP) might be a decrease of 1% in 2050, or even more (about 3%) in North Africa and in small Mediterranean islands (Malta, Cyprus), which are expected to be more sensitive to climate change.

• The Mediterranean is the most important tourist region of the world. Climate change will affect tourism by decreasing the tendency to travel from northern countries. In the future the south could be strongly affected by a gradual loss of tourists.

• Reduction of the land areas suitable for agriculture, reduction of crop yields.

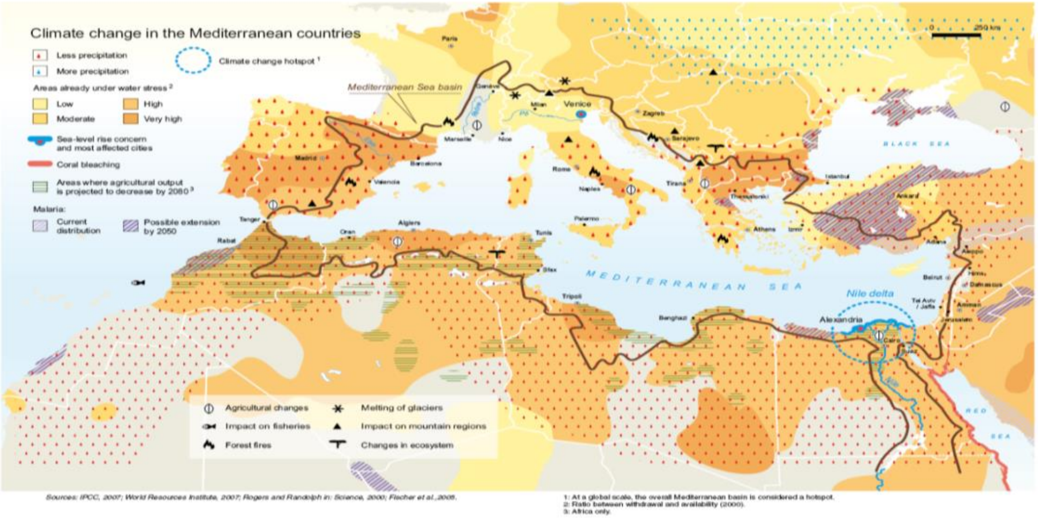
Examples of impacts of climate change on economy

• Water scarcity is today one of the main world issues.

• Because of the background environment and the climate change projections for the Middle East and North Africa (MENA), it will be even more important for this region in the future.

•Changes in precipitation patterns, intensity and frequency of extreme events, soil moisture, runoff, and evapotranspiration have already occurred. In the future, agricultural areas are projected to shrink with consequent changes for cropping systems.

• Water for agriculture was chosen by the ClimaSouth project to illustrate the linkages between high resolution climate data and impact assessment.



Climate data: general concepts

- Climate changes … need for models
- Modeling of the climate system, a challenging task
- Global Models…. and their limitations
- High resolution data: downscaling and regional models
- Data quality: uncertainty and sensitivity

Climate changes … need for models

- Extreme atmospheric values heavily affect human structures dedicated to food, water, energy and transports.

- It is a typical procedure to design infrastructures taking into account extreme values from the past historical information on weather and climate extremes and assuming stationarity of mean states, but such measures could not be able to guarantee safety conditions in the future.

- Since assessing changes in extremes is not trivial, there is a concrete need of realizing models which are expected to successfully predict the climate evolution over decades.

Climate models

Climate models are "*A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes ….Climate models are applied as a research tool to study and simulate the climate and for operational purposes, including monthly, seasonal and interannual climate predictions.*" (IPCC, 2014).

They are used to predict future changes climate features by means of a set of mathematical equations (Allaby, 2002)
The equations are solved numerically on a grid in which earth, ocean and atmosphere are discretized. Furthermore, several parameterizations are used.

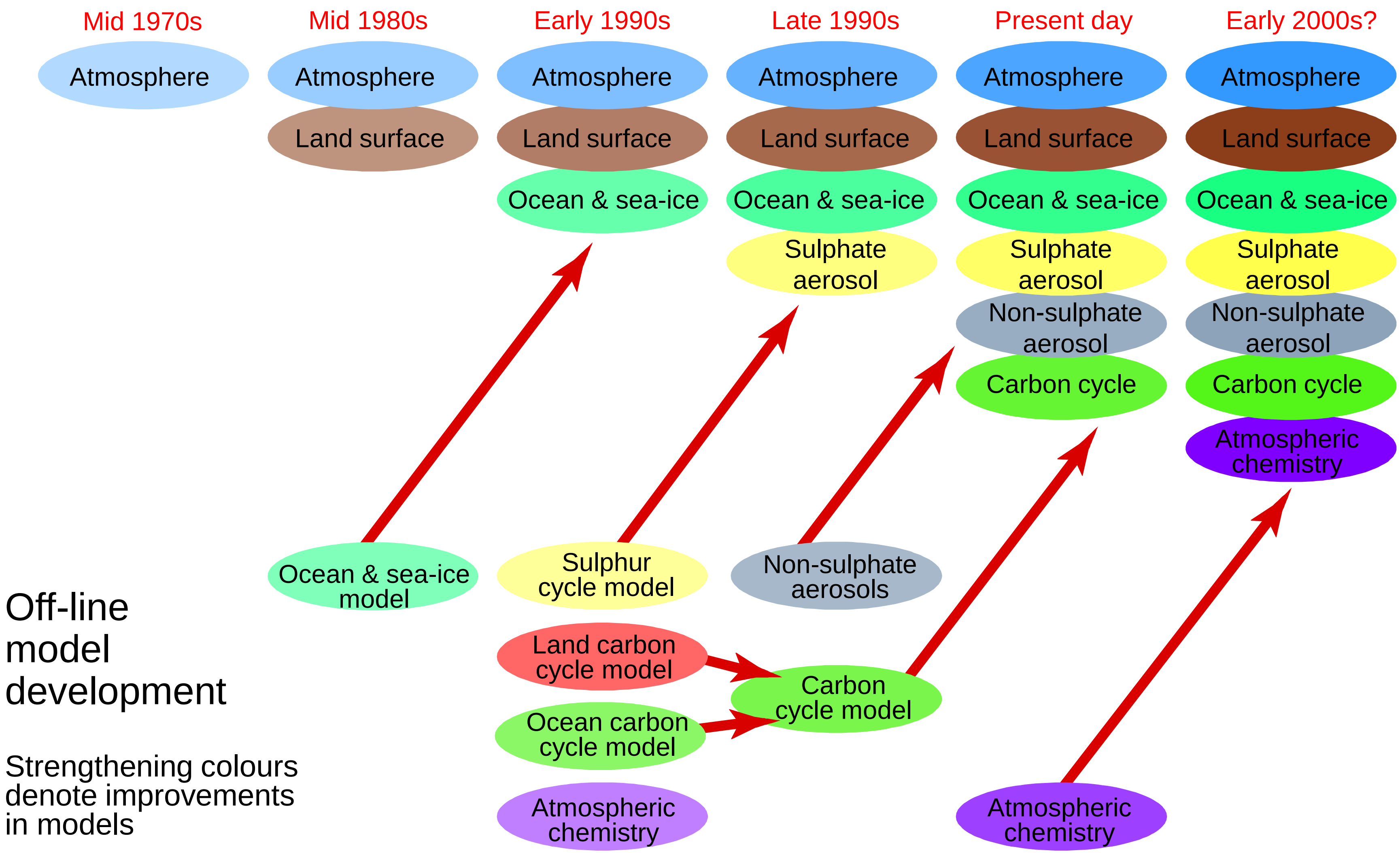
Global Climate Models (GCMs) are generally used to simulate the response of the climate to the increasing greenhouse gas concentrations. But they are characterized by a resolution not suitable to provide information at regional scale (Christensen et al., 1997).

- Allaby M. (2002) Encyclopedia of weather and climate, Revised Edition, Facts On File, Inc, New York.
- Christensen et al (1997) Validation of present-day regional climate simulations over Europe: LAM simulations with observed boundary conditions. Climate Dynamics. 13(7-8):489-506
- IPCC, 2014: Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 117-130.

Climate models: history

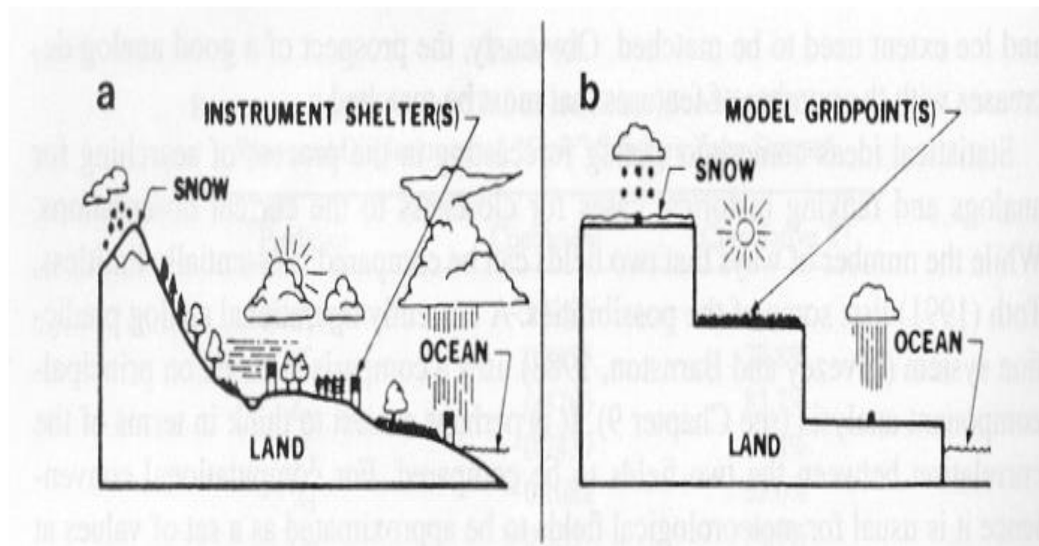
- **Arrhenius**, late 1800: zero - dimensions energy balance
- **One - dimension energy balance** (horizontal energy exchange)
- **Two - dimensional models** (able to simulate large scale energy transfers e.g. Hadley cell)
- **Two- dimensional models** including convection
- **Earth System Models** (intermediate complexity)
- **Modern General Circulation Models** (GCMs), based on physical equations

The Development of Climate models: Past, Present and Future



Regional Climate Models

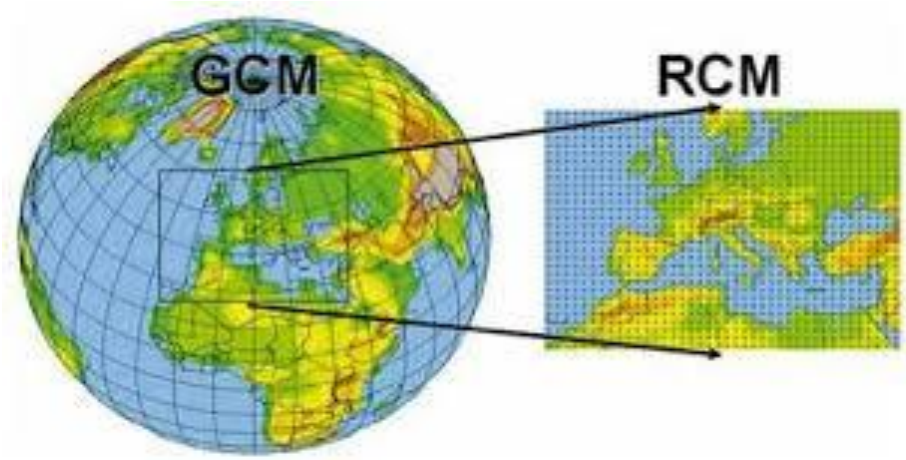
- GCMs guarantee physical consistency between variables but…
- There are important differences between the real world and its model representation.
- Small-scale effects (such as topography) important to local climate could be poorly represented in a GCM.
- Variables such as streamflow may not be represented explicitly by the GCM.
- GCMs cannot support impact studies and adaptation strategies.
- Different spatial scales of climate models and impact models (e.g. hydrological models).



Regional Climate Models

A **dynamical downscaling** can be performed by means of Regional Climate Models (RCMs), which use the output of GCMs as input data.
Nowadays, RCMs can adopt resolutions of very few kilometres, allowing a better description of surface characteristics and of relevant atmospherical processes (Giorgi et al., 2001).

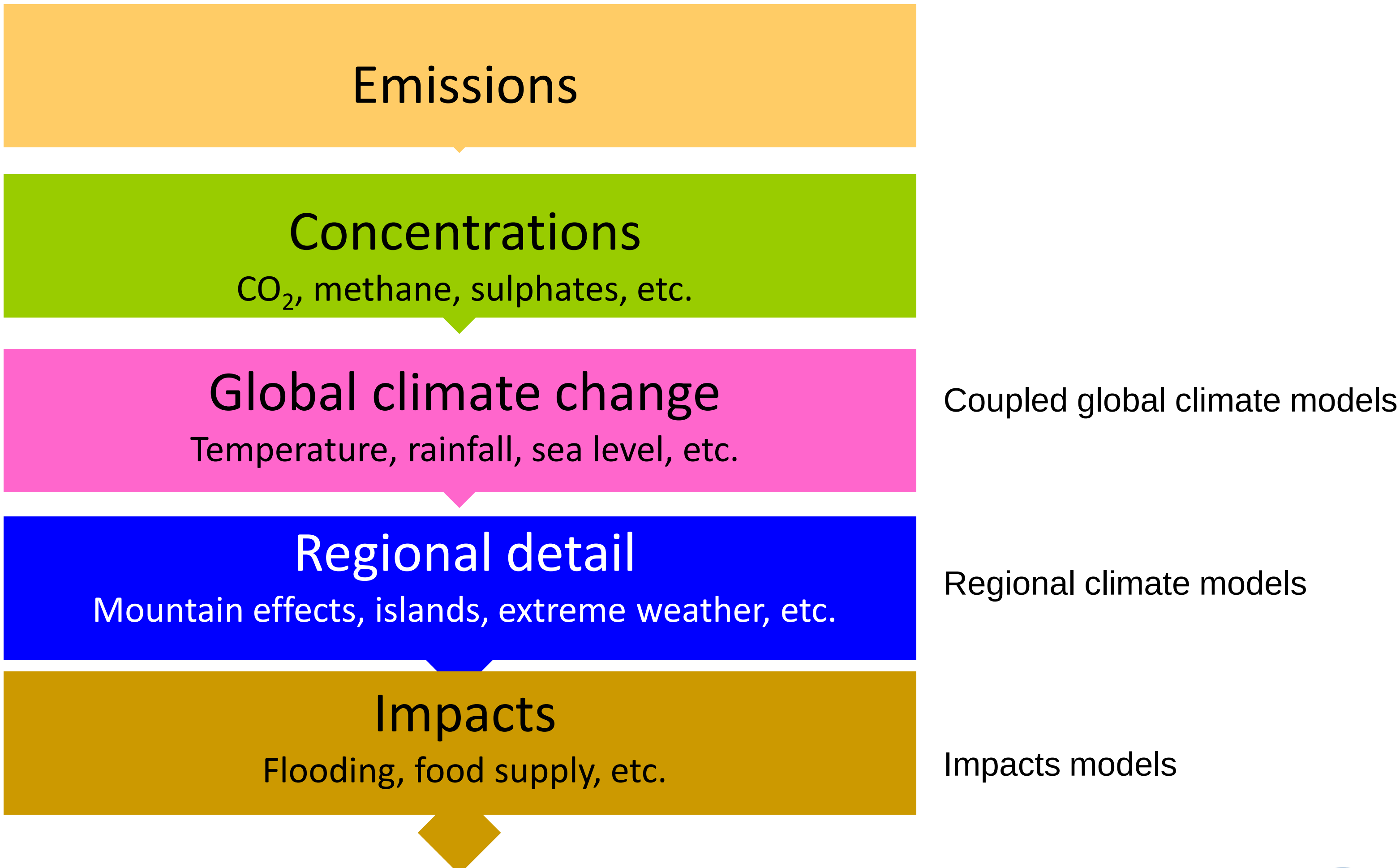
RCMs are especially suitable to assess changes expected in terms of extreme weather events, that are of great importance to develop adaptation strategies. Indeed, with respect to the GCMs, they better represent climate extremes (Rummukainen, 2010).



- Giorgi F. et al. (2001) Regional climate information-evaluation and projections. Climate Change 2001: The Scientific Basis. Contribution of Working Group to the Third Assessment Report of the Intergouvernmental Panel on Climate Change [Houghton, JT et al.(eds)]. Cambridge University Press, Cambridge, United Kongdom and New York, US
- Rummukainen M. (2010) *State-of-the-art with Regional Climate Models*, Wiley Interdisciplinary Reviews: Climate Change, 1(1): 82-96.

Predicting impacts of climate change

The main stages required to provide climate change scenarios for assessing the impacts of climate change.

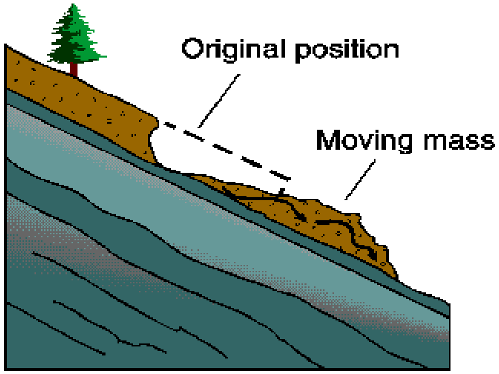


Use of data

Climate modelling communities interact with data in multiple ways:

- Historical climate data from various sources are used over control periods to calibrate climate models.
- Boundary conditions from Global Climate Models are needed to run Regional models.
- Impact community uses climate data as input for their models.

Evaluation of the effects of climate changes on landslides phenomena triggered by precipitation events (clay strain).



General considerations

• To respond to the needs of decision makers to plan for climate change, a variety of tools and datasets provide projected climate impacts at spatial/temporal scales much finer than those at which the projections are made.

• It is important to recognize the variety of assumptions behind the techniques used to derive such information and the limitations they impose on the results.

• The downscaling produces climatic information at scales finer than the initial projections, but this process involves additional data and assumptions, leading to further uncertainties and limitations of the results, a consequence that is often not made explicit to end-users.

General recommendations

- International organizations currently provide no official guidance that assists researchers and decision makers in determining climate projection, downscaling methods, and data sources that best meet their needs.

- Important considerations and recommendations to keep in mind when dealing with fine-scale information on climate change.

    1. Downscaling relies on the assumption that local climate is a combination of large-scale climatic/atmospheric features (global, continental, regional) and local conditions (topography, land surface properties). Representation of the latter is generally beyond the capacity of current GCMs.

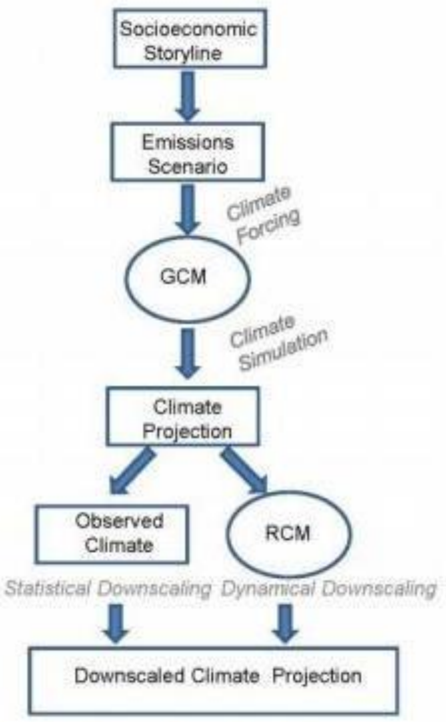
General recommendations

2. Deriving climate projections at local scales is a multistep process. At each step, assumptions and approximations are made. Uncertainties arise from different sources and need to be kept in mind, whether explicitly quantified or not.

3. Information on downscaling and the limitations of the results are often not appropriately highlighted, leading the user to believe that the results are "**true**" and valid at the resolution presented.

4. Given the diversity of developed approaches, it is recommended to partner with a climate scientist or downscaling expert who can help to evaluate the needs, relevant techniques, and limitations of the results.

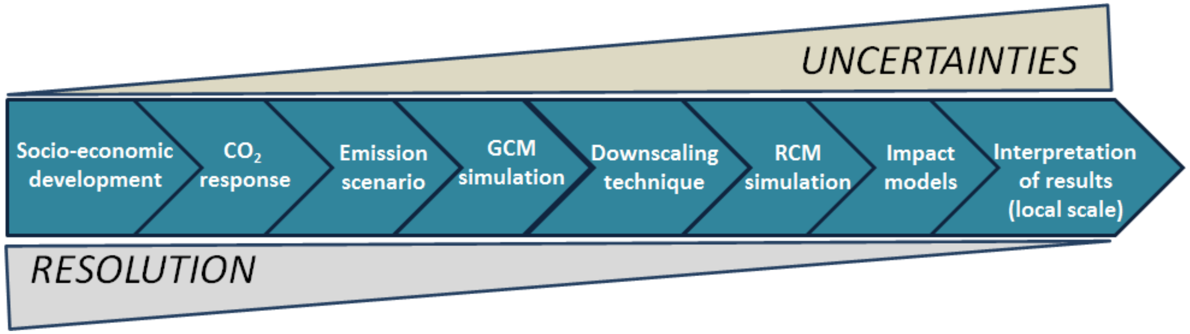
FIGURE I. ILLUSTRATION OF THE COMPONENTS INVOLVED IN DEVELOPING GLOBAL AND REGIONAL CLIMATE PROJECTIONS



Source: Daniels et al., 2012

The Water Imbalance

Water balance models are a suitable tool to support water agencies in the better management of agricultural water resources.
The use of climate data as input to such impact models allows their use for simulating both current and future water need. However, the accuracy of model outputs depends on climate data reliability.



How to manage the uncertainty?

There are a number of sources of uncertainties related to regional climate model assessment:

Parameterizations of RCM	⇨	Sensitivity analysis
Boundary conditions	⇨	Usage of different data forcing
Validation dataset reliability	⇨	Usage of different validation datasets
Choice of the RCM	⇨	Multi model ensemble
Choice of the future scenarios	⇨	Multi scenario ensemble

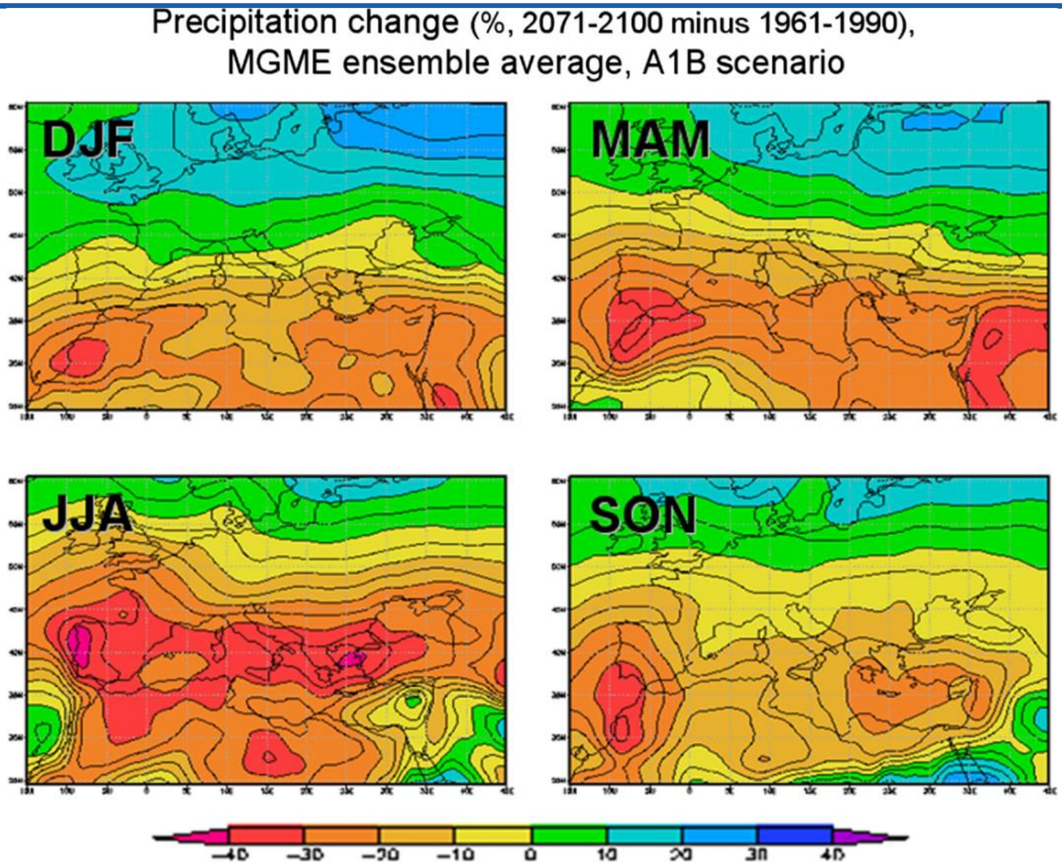
Relevant climate simulations for ClimaSouth

Different climate datasets are relevant for ClimaSouth:

Global:
- CMIP3: Coupled Model Intercomparison Project (phase 3)
- CMIP5: Coupled Model Intercomparison Project (phase 5)

Regional:
- All the European simulations (e.g. Prudence, Ensembles)
- Euro-Cordex
- Med-Cordex
- Mena-Cordex

An example of GCM projections

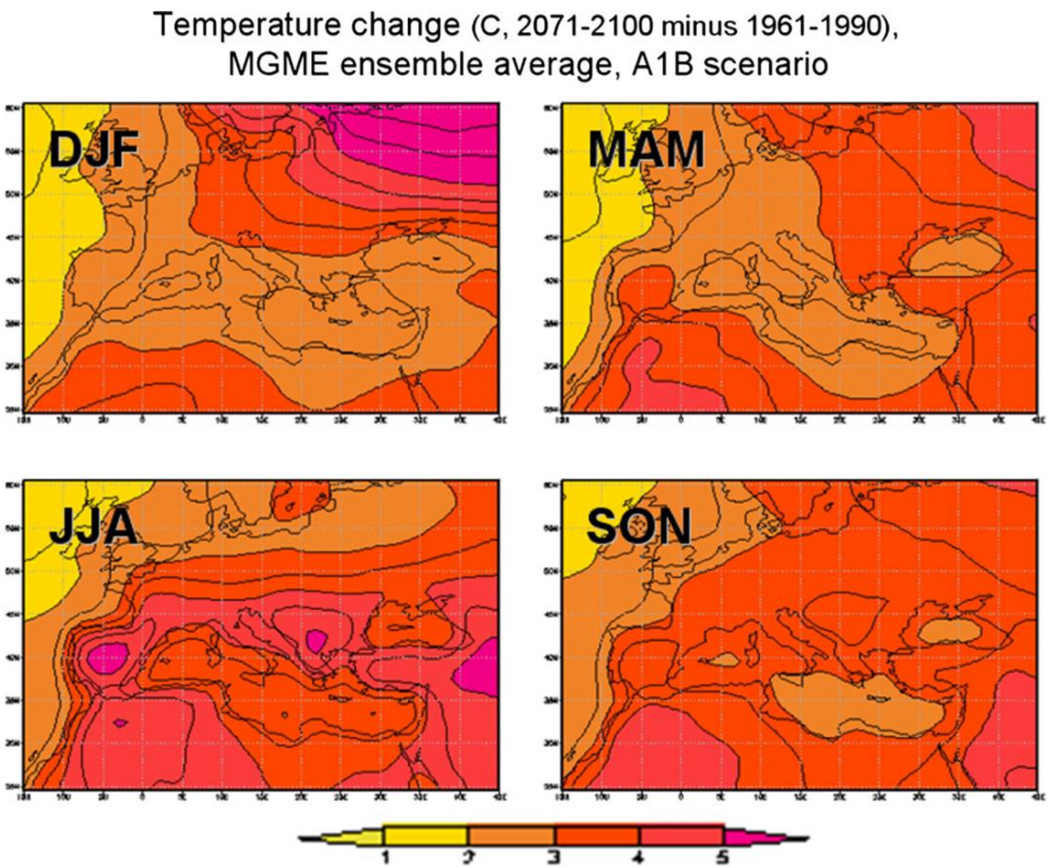


Precipitation change: 2071-2100 minus 1961-1990, A1B scenario

General reduction of precipitation in the Mediterranean area, especially in JJA, MAM and SON.
In JJA, the area affected by reduction has its maximum extension, including mostly of European western area.
In DJF, the transition area between positive and negative precipitation change moves southward and crosses the northern Iberian, Italian and Balkan peninsulas.

F. Giorgi, P. Lionello, Climate change projections for the Mediterranean region, Global and Planetary Change 63 (2008) 90–104

An example of GCM projections



Surface air temperature change: 2071-2100 minus 1961-1990, A1B scenario

In JJA, the maximum warming is registered. In DJF and MAM, the maximum warming magnitudes are found over continental northeastern Europe, at least partially in response to reduced snow cover there. In SON, the warming is more equally distributed throughout the European land areas.

Source: Giorgi and Lionello (2008)

The PRUDENCE project

- PRUDENCE (2001-2004): Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects.

- The main objectives of the projects are:
  a) to address the existing deficiencies in projections of future climate change;
  b) to quantify our confidence in predictions of future climate and its impacts;
  c) to interpret these results in relation to European policies for adapting to or mitigating climate change.

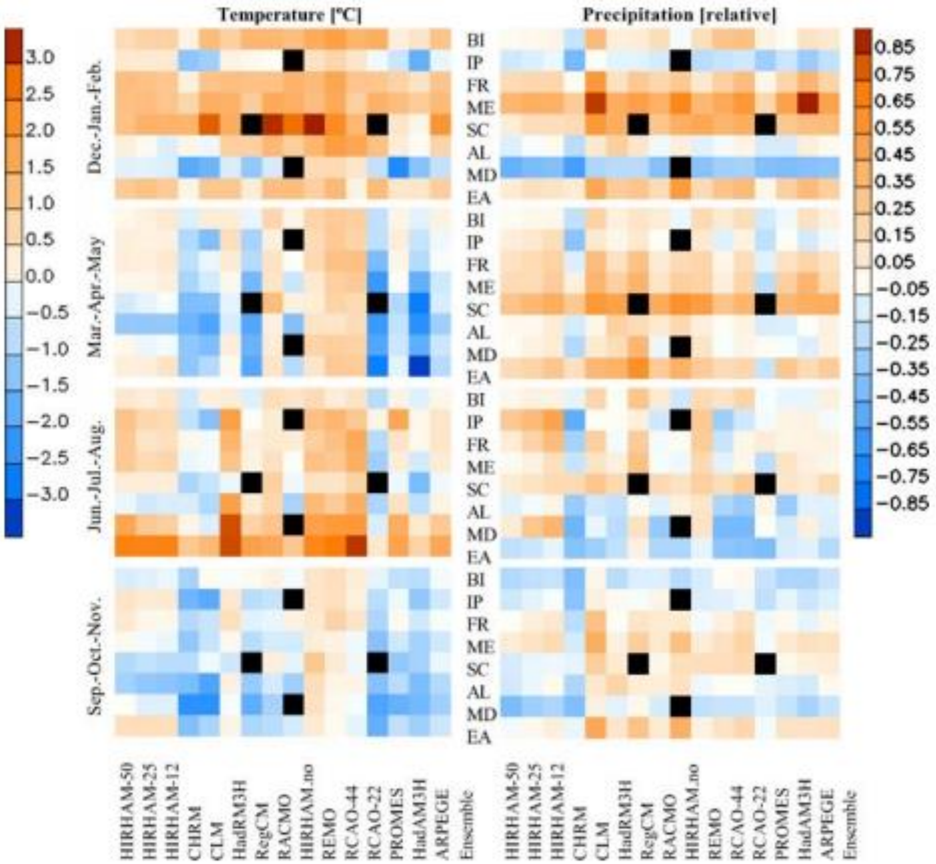
- A wide range of global and regional climate models was used.

- Regional simulations performed at a spatial resolution of 50 km, driven at lateral boundaries by different global models.

- Reference period: 1961 – 1990. Future period: 2071 – 2100 (scenarios A2 and B2).

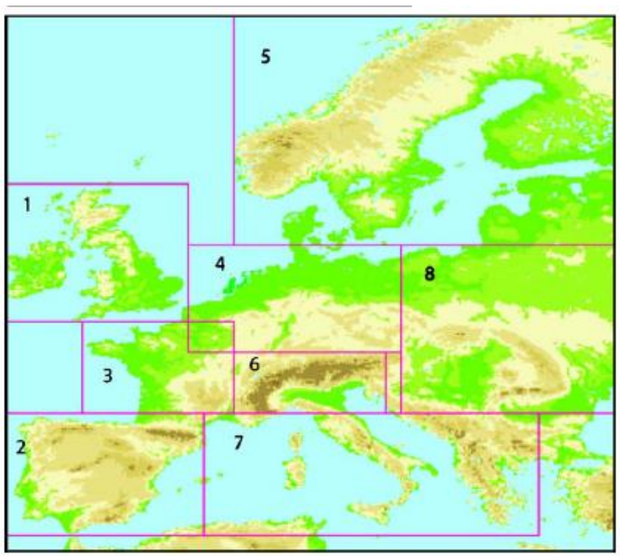
http://prudence.dmi.dk

Results of PRUDENCE: bias



Jacob et al. (2007) reports a performance evaluation of PRUDENCE simulations. CRU data have been used as reference.

A general warm bias in the extreme seasons and a tendency to cold biases in the transition ones is found. Areas affected by warm (cold) bias in DJF are characterized by a wet (dry) bias; the opposite occurs in JJA.

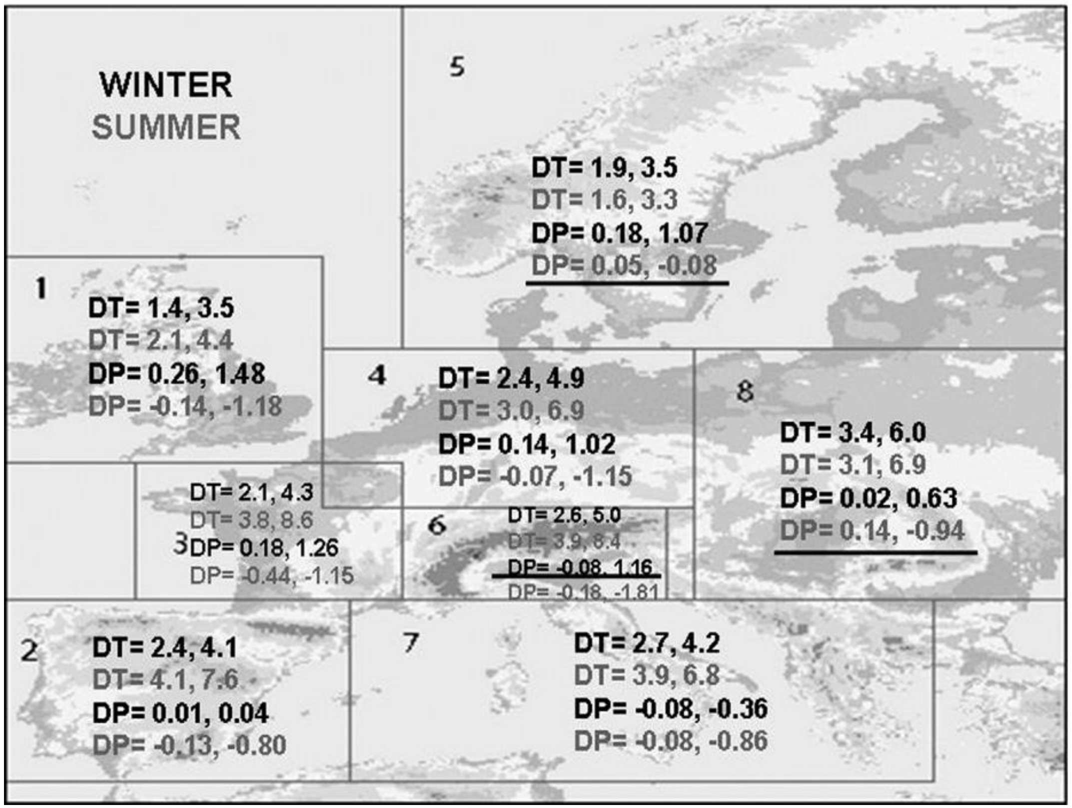


- Rows: analysis areas
- Columns: models
- Left: temperature
- Right precipitation

Jacob et al, 2007 "An inter-comparison of regional climate models for Europe: model performance in present-day climate." Climatic Change 81:31–52

Results of PRUDENCE: projections

Surface air temperature (DT, C) and precipitation (DP, %)
Change, 2071-2100 minus 1961-1990, A2 scenario



A broad agreement between the PRUDENCE and global projections over the Mediterranean region can be observed.

The summer drying and warming in all Mediterranean sub-regions is evident also in the PRUDENCE projections. The only discrepancy with the global data occurs when comparing precipitation changes over Iberian peninsula.

All models agree on the sign of the precipitation change signal.

.

Source: Giorgi and Lionello (2008)

The ENSEMBLES project

- The ENSEMBLES project was supported by the 6th Framework Programme (2004 – 2009).

- A number of regional limited-area models were used to downscale global projections over Europe at 25 and 50 km resolution over the second half of the XX century and along the XXI century.

- The value of the ENSEMBLES project is the execution of multiple climate models (‘ensembles’), a method known to improve the accuracy and reliability of forecasts.

- This probabilistic information will assist policy makers in determining future strategies to address climate change.

- Climate projections were carried out under the assumptions of the SRES - A1B scenario.

(http://www.ensembles-eu.org)

The ENSEMBLES project

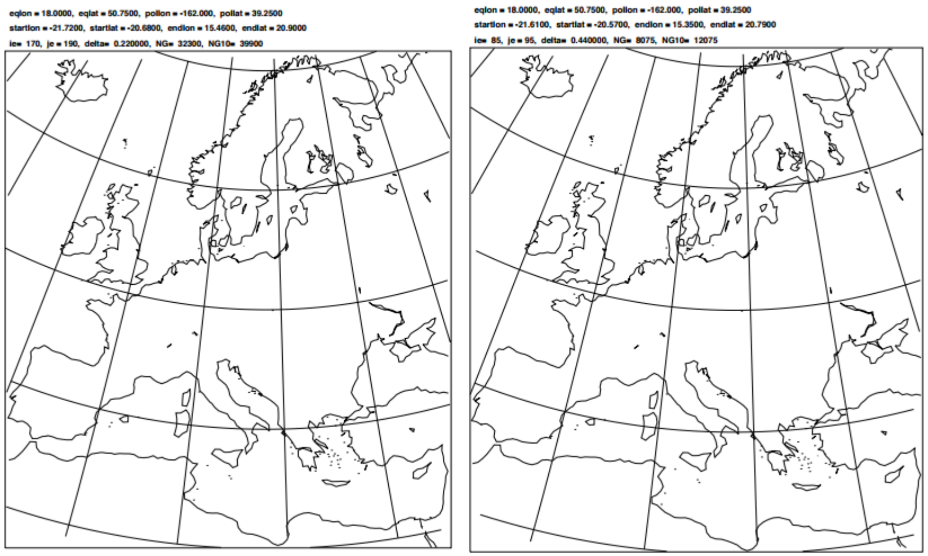
The aims of the project:

- ✓ Development of an ensemble prediction system for climate change, based on the principal state-of-the-art, high resolution, global and regional models developed in Europe, validated against high resolution datasets for Europe.

- ✓ Quantification and reduction of the uncertainty in the representation of physical, chemical, biological and human-related feedbacks in the Earth System.

- ✓ Increase of the exploitation of the results, by linking the outputs of the ensemble prediction system to a range of applications, including agriculture, health, food security, energy, water resources, insurance and weather risk management.

ENSEMBLES RCM Minimum Area



0.22 degree (25km) grid mesh | 0.44 degree (50km) grid mesh

Results of ENSEMBLES project (2021-2050 m 1961-1990)

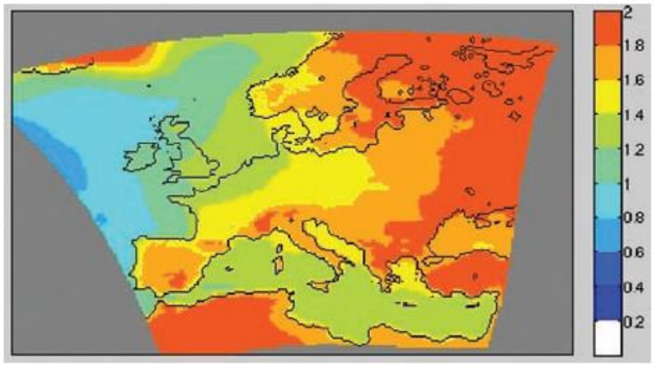


Figure 6.3: Climate-change signal (2021–2050 minus 1961–1990) for annual near-surface (2 m) temperature (°C) for the multi-model mean of the ENSEMBLES RCMs.

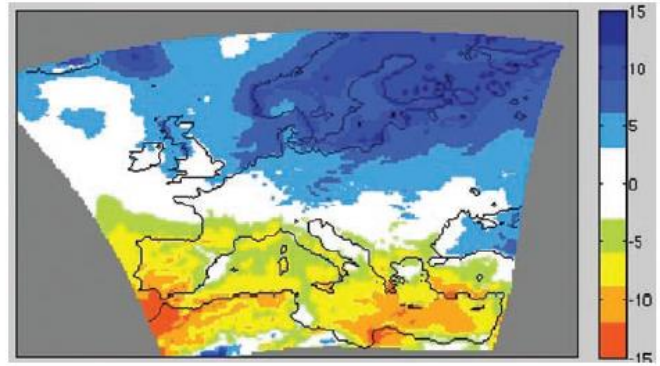


Figure 6.5: Climate-change signal (2021–2050 relative to 1961–1990) for annual precipitation total (%) for the multi-model mean of the ENSEMBLES RCMs.

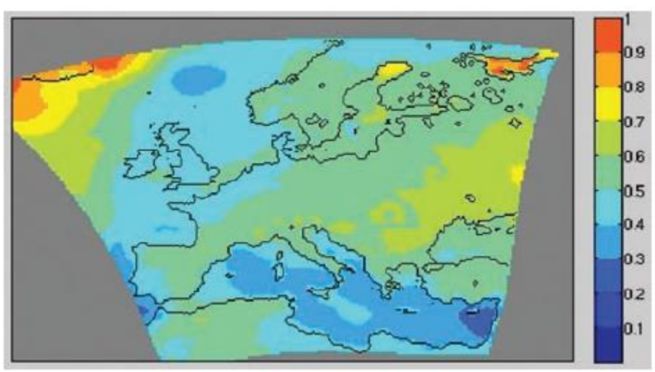


Figure 6.4: Inter-model standard deviation of the climate-change signal (2021–2050 minus 1961–1990) for annual near-surface (2 m) temperatures (°C) for the ENSEMBLES RCMs.

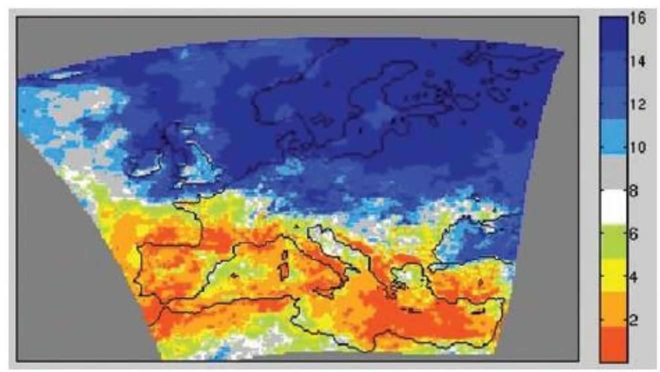


Figure 6.6: Number of RCMs which show an increase in precipitation (2021–2050 relative to 1961–1990) for the ENSEMBLES RCMs.

Temperature

The signal of the multi-model mean is positive over the whole Europe and is much larger than the standard deviation (robust signal).

Precipitation

Europe is divided into two regimes (increase in the north and decrease in the south). It is a robust pattern: all models agree on the increase in the north and only two to four (out of sixteen) disagree with the decrease in the south.

These findings are in general agreement with PRUDENCE project results.

Van der Linden P. and J.F.B. Mitchell (eds.) 2009: ENSEMBLES: Climate Change and its Impacts: Summary of research and results from the ENSEMBLES project. Met Office Hadley Centre, FitzRoy Road, Exeter EX1 3PB, UK. 160pp.

Results of ENSEMBLES project

Location of points with a significant positive (light grey) or negative (dark grey) change in precipitation in winter (left) and summer (right).

The robustness of seasonal changes in precipitation is shown.

In large parts of Europe, significant and spatially coherent patterns in winter and summer precipitation trends are visible, although there are also quite extensive areas with no significant patterns.
For much of southern Europe the only clear signal is the summer decrease. At the same time, there are areas such as the south-east Iberian Peninsula, the Alps and parts of central Europe with no clear signal in either season.

Source: Van der Linden P. and J.F.B. Mitchell (eds.) 2009.

The CORDEX initiative

WCRP
World Climate Research Programme
CORDEX
Coordinated Regional Climate Downscaling Experiment

The CORDEX vision is to advance and coordinate the science and application of regional climate downscaling through global partnerships.

• CORDEX (COordinated Regional climate Downscaling Experiment) is a WCRP (World Climate Research Programme) project.

• The CORDEX vision is to advance and coordinate the science and application of regional climate downscaling through global partnerships.

• In the framework of CORDEX initiative, both dynamical and empirical-statistical downscaling models are used to produce improved climate scenarios at high resolution, considering multiple forcing GCMs from the CMIP5 archive.

(http://wcrp-cordex.ipsl.jussieu.fr/)

The CORDEX initiative

The CORDEX vision is to advance and coordinate the science and application of regional climate downscaling through global partnerships.

The aim of this initiative is:

- ✓ to better understand relevant regional/local climate phenomena, their variability and changes, through downscaling;
- ✓ to evaluate and improve regional climate downscaling models and techniques;
- ✓ to produce coordinated sets of regional downscaled projections worldwide;
- ✓ to foster communication and knowledge exchange with users of regional climate information.

<u>14 CORDEX regions</u>:

South America, Central America, North America, **Europe**, Africa, South Asia, East Asia, Central Asia, Australasia, Antarctica, Artic, **Mediterranean** domain, **Mena** domain, South East Asia.

The CORDEX initiative (http://wcrp-cordex.ipsl.jussieu.fr/)

http://cordexesg.dmi.dk/esgf-web-fe/

Peer Nodes

- ANL Node
- BADC Node
- BNU Node
- CMCC Node
- DKRZ Node
- DKRZ CMIP5 Node
- NOAA-GFDL Node
- IPSL Node
- NASA-GSFC Node
- NASA-JPL Node
- NCI Node
- NERSC Node
- ORNL Node
- PCMDI Node
- SMHI-LIU-NSC Node
- DMI Node

Current Selections

- remove all
- (x) project:CORDEX
- (x) domain:EUR-11
- (x) variable long name:Land Area Fraction
- (x) experiment:evaluation

EUR-11 | Search

Examples: *temperature*, "*surface temperature*", *climate AND project:CMIP5 AND variable:hus*.
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- Ensemble
- Domain
- Driving Model
- Downscaling realisation
- Data Node

The CORDEX initiative (http://wcrp-cordex.ipsl.jussieu.fr/)

5.2 DRS File naming

The names of the files in CORDEX archives are made up of the DRS elements described above. The elements are separated by underscores ('_') and must appear in the following order[q]:

VariableName_Domain_GCMModelName_CMIP5ExperimentName_CMIP5EnsembleMember_ RCMModelName_RCMVersionID_Frequency[_StartTime-EndTime].nc

Constant fields (Frequency=*fx*, e.g., *orog*) do NOT have the *StartTime-EndTime* element in their file names. The suffix 'nc' is mandatory

tas_EUR-11_ECMWF-ERAINT_evaluation_r1i1p1_DMI-HIRHAM5_v1_mon_198901-199012.nc
tas_EUR-11_MPI-M-MPI-ESM-LR_historical_r1i1p1_SMHI-RCA4_v1_mon_199101-200012.nc
tas_EUR-11_ICHEC-EC-EARTH_rcp45_r12i1p1_SMHI-RCA4_v1_mon_200601-201012.nc
tas_EUR-11_CNRM-CERFACS-CNRM-CM5_rcp85_r1i1p1_SMHI-RCA4_v1_mon_200601-201012.nc

The EURO-CORDEX simulations

With respect to already existing coordinated ensembles of regional climate simulations over Europe, EURO-CORDEX simulations consider new RCP scenarios at increased spatial resolution.
EURO-CORDEX simulations focus on grid-sizes of about 12 km (0.11 degree).
Auxiliary simulations with the standard CORDEX resolution of about 50 km (0.44 degree) are being conducted additionally.

http://euro-cordex.net/About-EURO-CORDEX.1864.0.html

Periods:

- Hindcast (ERA Interim): 1989 - 2008
- Control: 1951 - 2005 (1981 - 2010, 1951-80)
- Scenario: 2006 - 2100 (2041-71, 2011-40, 2071-2100)

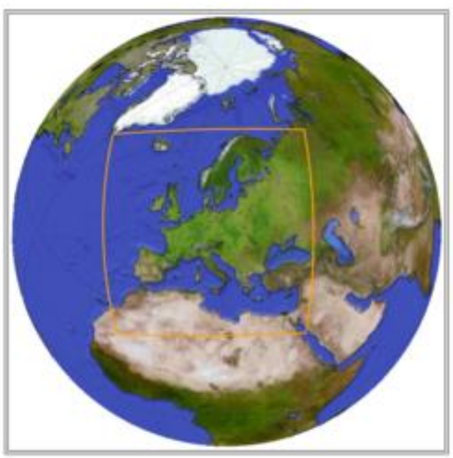
The EURO-CORDEX simulations

With respect to already exi
over Europe, the EURO-CORD
spatial resolution.
EURO-CORDEX simulations w
Auxiliary simulations with th
are being conducted additior

Region 4: Europ

A) For r
RotPole
TLC (331
Nx=106
Ny=103

B) For n
TLC (31
CNB (1.
TRC (64.
CWB (33
CPD (9.7
CEB (44.
BLC (35
CSB (12.
BRC (36.

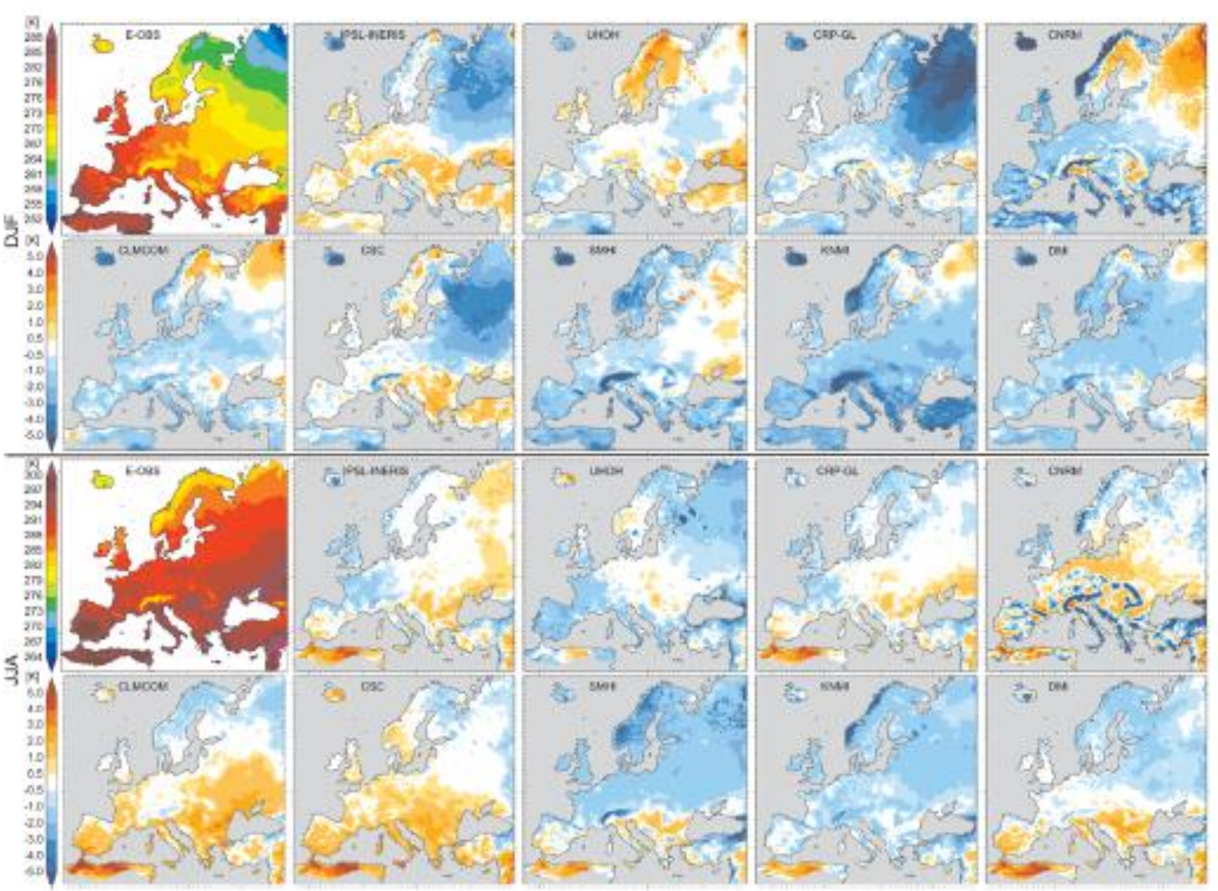


Ref: Description of the CORDEX domains
(23/06/2015 version)

Website:
• EUR

EUR-11	ALADIN53	CNRM-CERFACS-CNRM-CM5
EUR-11	ALADIN53	ECMWF-ERAINT
EUR-11	CCLM4-8-17	CNRM-CERFACS-CNRM-CM5
EUR-11	CCLM4-8-17	ECMWF-ERAINT
EUR-11	CCLM4-8-17	ICHEC-EC-EARTH
EUR-11	CCLM4-8-17	MOHC-HadGEM2-ES
EUR-11	CCLM4-8-17	MPI-M-MPI-ESM-LR
EUR-11	HIRHAM5	ECMWF-ERAINT
EUR-11	HIRHAM5	ICHEC-EC-EARTH
EUR-11	RACMO22E	ECMWF-ERAINT
EUR-11	RACMO22E	ICHEC-EC-EARTH
EUR-11	RACMO22E	MOHC-HadGEM2-ES
EUR-11	RCA4	CNRM-CERFACS-CNRM-CM5
EUR-11	RCA4	ECMWF-ERAINT
EUR-11	RCA4	ICHEC-EC-EARTH
EUR-11	RCA4	IPSL-IPSL-CM5A-MR
EUR-11	RCA4	MOHC-HadGEM2-ES
EUR-11	RCA4	MPI-M-MPI-ESM-LR
EUR-11	RegCM4-2	ECMWF-ERAINT
EUR-11	WRF331F	ECMWF-ERAINT
EUR-11	WRF331F	IPSL-IPSL-CM5A-MR

Results of EURO-CORDEX initiative: T2m bias



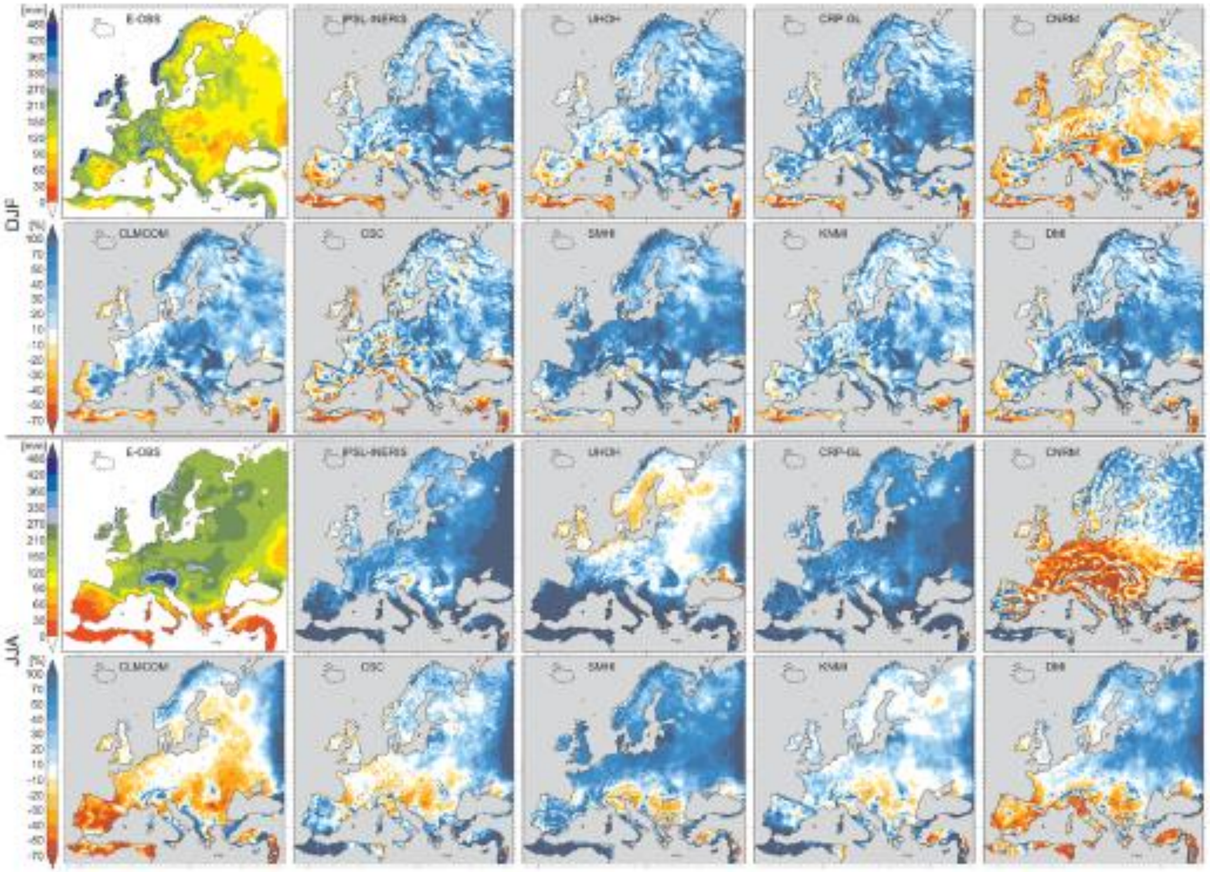
In Kotlarski et al. (2014), the evaluation of EURO-CORDEX simulations is reported, considering the period 1989-2008.
Results are compared with E-OBS dataset.

Temperature is generally underestimated in winter; in summer, some models show a warm bias over southern Europe.

- Upper Rows: winter
- Lower rows: summer

Kotlarski et al., 2014 "Regional climate modeling on European scales: a joint standard evaluation of the EURO-CORDEX RCM ensemble." Geoscientific Model Development Discussions 7.1 : 217-293.

Results of EURO-CORDEX initiative: precipitation bias



Precipitation is generally overestimated in winter, especially over central and eastern Europe.

Also in summer most of the models are characterized by a wet bias, although some simulations show an underestimation over the Mediterranean region.

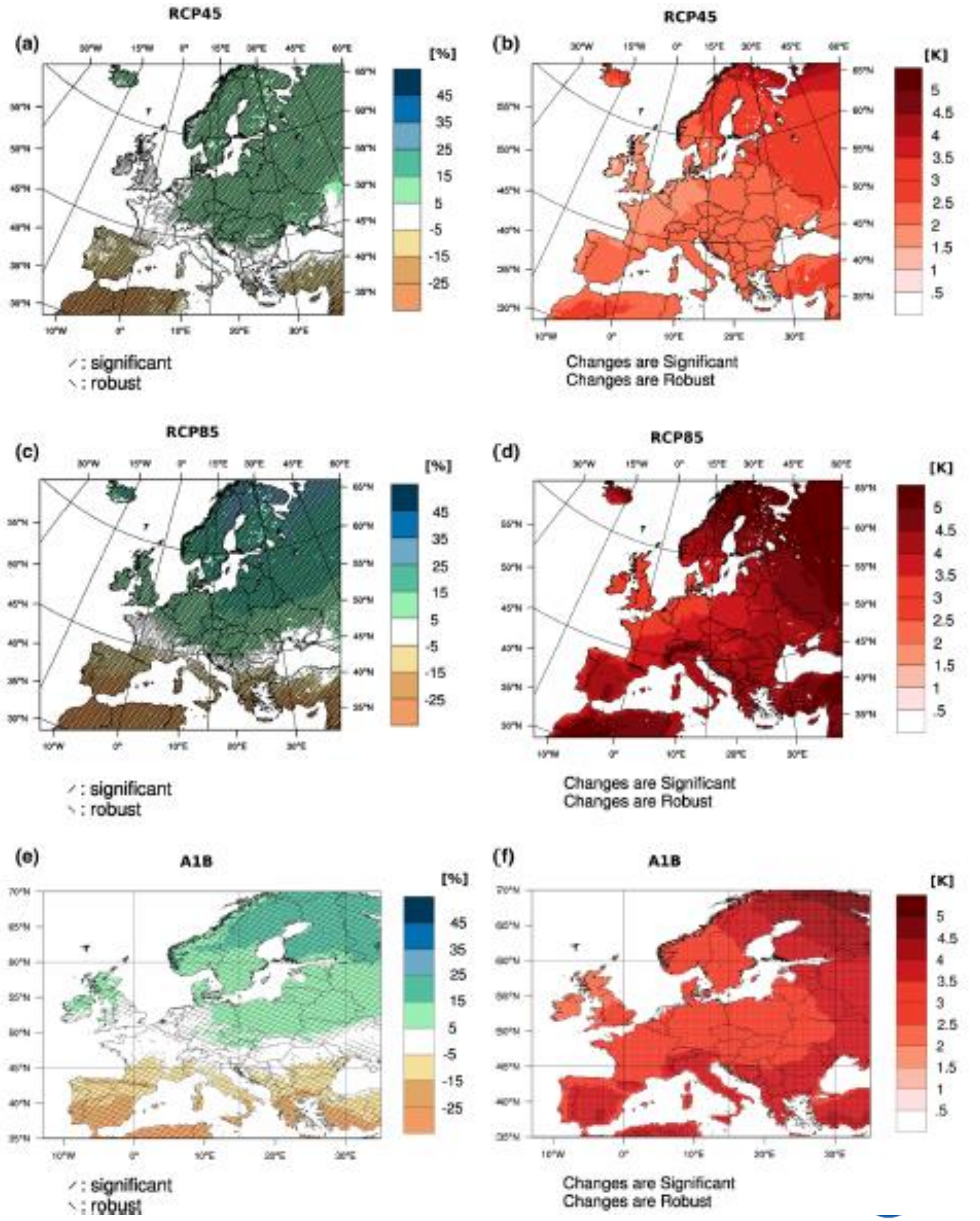
- Upper Rows: winter
- Lower rows: summer

Source: Kotlarski et al., 2014

Results of EURO-CORDEX initiative: climate projections

Jacob et al. (2014) analyzed climate projections under RCP4.5 and RCP8.5 scenarios of EURO-CORDEX simulations. Comparisons with ENSEMBLES simulations under A1B scenario were made.

For temperature, under RCP8.5 scenario stronger temperature changes are expected with respect to those projected with RCP4.5.
For precipitation, less differences are found between the two scenarios.



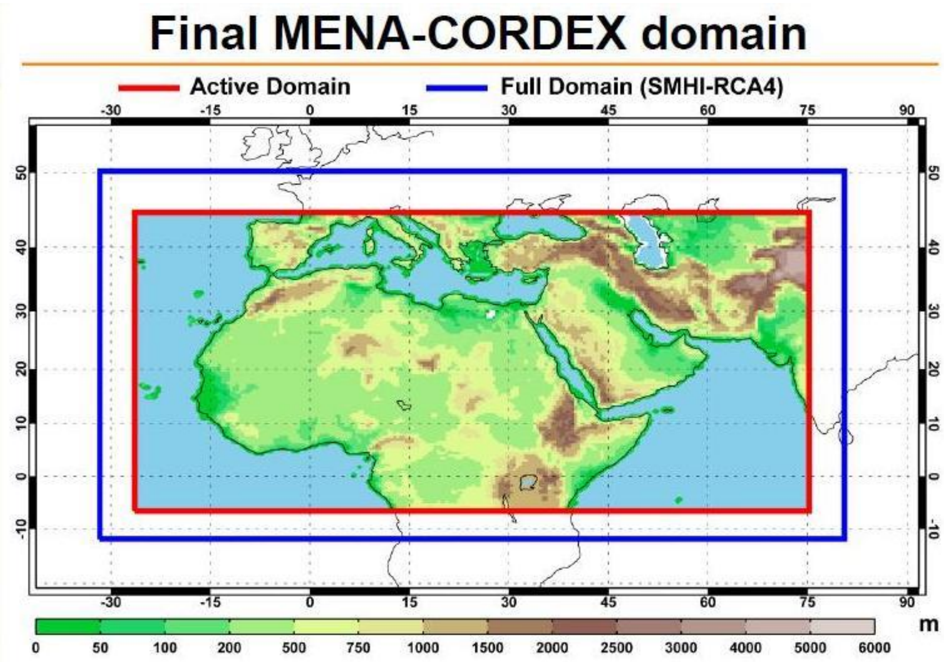
(2071-2100 m 1971-2000)

Jacob et al., 2014 "EURO-CORDEX: new high-resolution climate change projections for European impact research." Reg Environ Change 14:563-578.

The MENA-CORDEX simulations

High resolution climate projections over MENA-CORDEX domain are needed for the assessment of impacts on water resources in the Arab region. Importance is confirmed by the establishment of the RICCAR initiative, coordinated by the United Nations Economic and Social Commission for Western Asia (UN-ESCWA).

A first step within RICCAR was to establish a common domain for regional downscaling…. advantages to follow the CORDEX standards became apparent.

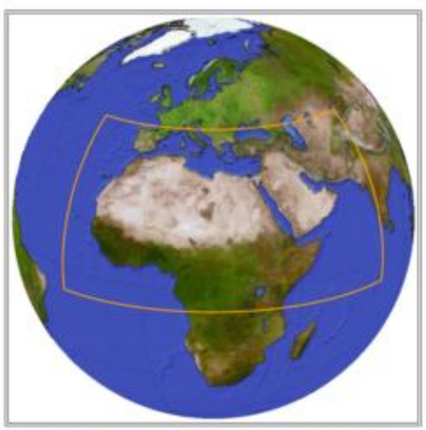


No clear guidance to select a domain (avoiding complex topography and regions of strong convection at the boundaries).
A sensitivity has been performed considering several domain configurations, in order to establish the final domain.
5 different domains were analyzed.

The MENA-CORDEX simulations

The MENA-CORDEX domain is characterized by a complex topography, including highland areas (e.g., Atlas Mountains, Ethiopian Highlands, Iranian and Anatolian plateaus), wide coastal areas and desert areas (Sahara in Africa and Rub Al-Khali in the Arabian Peninsula).
It is characterized by different climate conditions.
So, it represents a challenging domain for climate simulations.

Region 13: Middle East North Africa (MENA)



Ref: Description of the CORDEX domains

A) For rotated polar RCMs (in rotated coordinates):

RotPole (180.0; 90.0)
TLC (333.6; 44.88)
Nx=232
Ny=118

B) For non-rotated polar RCMs (in actual coordinates):

TLC (333.0.; 45.0)
CNB (24.5; 45.0)
TRC (76.0; 45)
CWB (333.0; 19.0)
CPD (24.5; 19.0)
CEB (333.0; 19.0)
BLC (333.0; -7)
CSB (24.5; -7)
BRC (76.0; -7)

IPCC (2007) Climate Change 2007: impacts, adaptation and vulnerability. In: Parry ML, Canziani OF, Palutikof JP, van der Linden J, Hanson CE (eds) Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, p 976 Geneva, Switzerland, pp. 117-130.

The MENA-CORDEX simulations

The MENA-CORDEX domain is characterized by a complex topography, including highland areas (e.g., Atlas Mountains, Ethiopian Highlands, Iranian and Anatolian plateaus), wide coastal areas and desert areas (Sahara in Africa and Rub Al-Khali in the Arabian Peninsula).
It is characterized by different climate conditions.
So, it represents a challenging domain for climate simulations.
Furthermore, it has been identified as one of the most prominent climate change "hot spots" (IPCC 2007).

Region 13: Middle East North Africa (MENA)

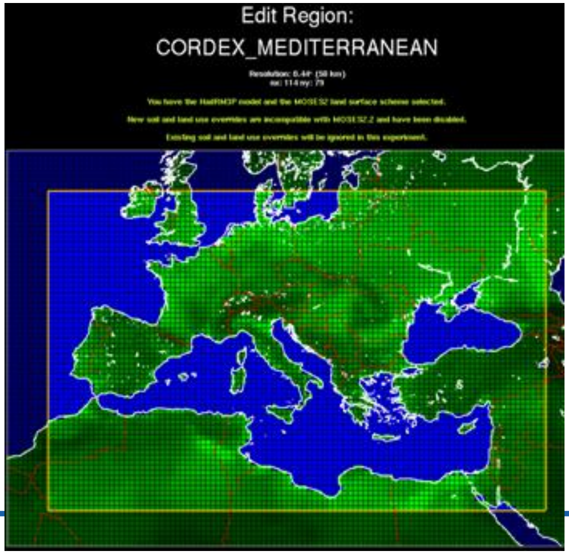
Ref: Description of the CORDEX domains

MNA-22	RCA4	ECMWF-ERAINT
MNA-22	RCA4	ICHEC-EC-EARTH
MNA-22	RCA4	NOAA-GFDL-GFDL-ESM2M
MNA-44	RCA4	CNRM-CERFACS-CNRM-CM5
MNA-44	RCA4	ECMWF-ERAINT
MNA-44	RCA4	ICHEC-EC-EARTH
MNA-44	RCA4	NOAA-GFDL-GFDL-ESM2M

IPCC (2007) Climate Change 2007: impacts, adaptation and vulnerability. In: Parry ML, Canziani OF, Palutikof JP, van der Linden J, Hanson CE (eds) Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, p 976 Geneva, Switzerland, pp. 117-130.

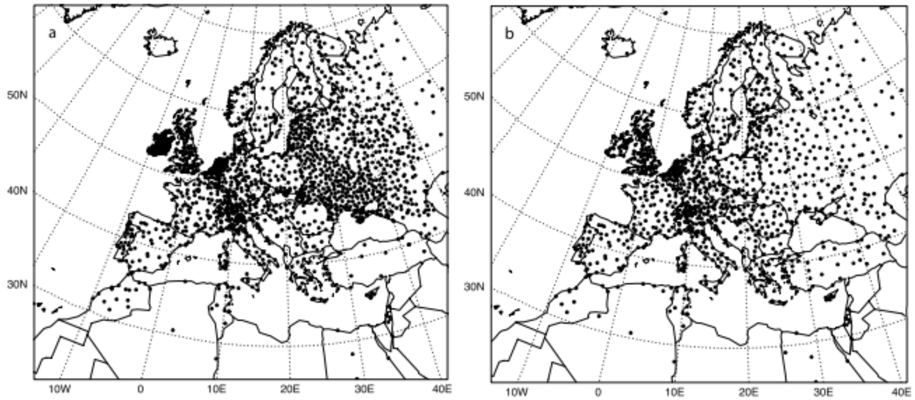
The Med - CORDEX initiative

- Med-CORDEX has been proposed by the Mediterranean climate research community as a follow-up of previous and existing initiatives.
- Med-CORDEX takes advantage of new very high-resolution Regional Climate Models (RCM, up to 10 km).
- Med-CORDEX uses new fully coupled Regional Climate System Models (RCSMs), coupling the various components of the regional climate.
- Med-CORDEX is a unique framework where research community will make use of both regional atmospheric, land surface, river and oceanic climate models and coupled regional climate system models for increasing the reliability of past and future regional climate information.



E-OBS dataset

It is an European gridded dataset at high resolution (0.25° x 0.25°) for precipitation, temperature (mean, minimum and maximum values) and sea level pressure for the period 1950-2013. This dataset has been designed to provide the best estimate of grid box averages rather than point values to enable direct comparison with RCMs.



It was constructed through interpolation of the most complete collection of station data over wide Europe.

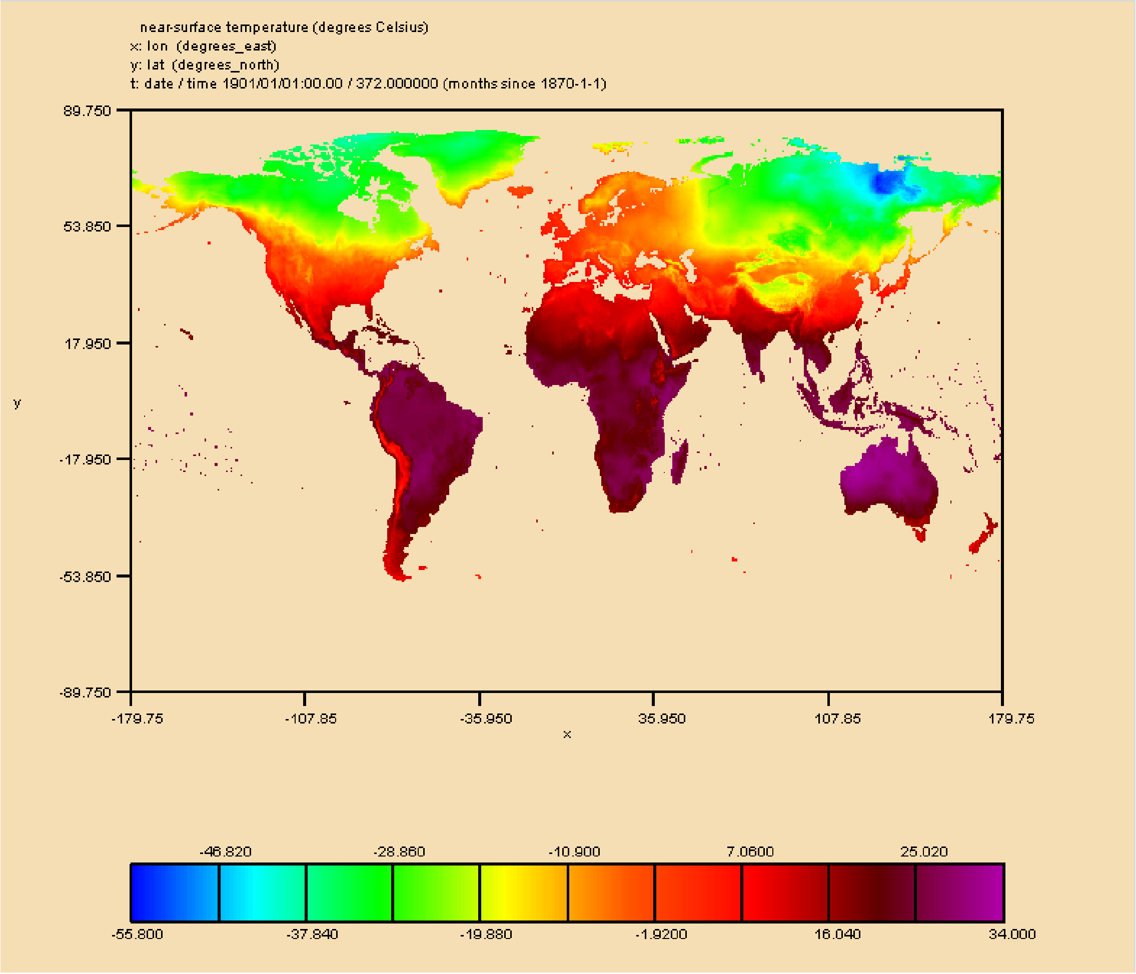
http://www.ecad.eu/download/ensembles/ensembles.php

from ECA&D (European Climate Assessment & Dataset)

Haylock et al., 2008. A European daily high-resolution gridded data set of surface temperature and precipitation for 1950-2006, Journal of Geophysical Research, 113(D20).

CRU dataset

It has been provided by the Climate Research Unit of University of East Anglia.
It is a gridded dataset, statistically interpolated from monthly station observations to a regular terrestrial grid at 0.5° spatial resolution. It includes several variables, such as precipitation, temperature (mean, minimum and maximum) and cloud cover.



http://www.cru.uea.ac.uk/

from the Climate Research Unit

Mitchell and Jones, 2005. An improved method of constructing a database of monthly climate observations and associated high-resolution grids- Int.J. Climatol 25(6), 693-712

Harris I, Jones PD, Osborn TJ, Lister DH (2014) Updated high-resolution grids of monthly climatic observations – the CRU TS3.10 dataset. Int. J. Climatol. 34 (3):623-642. doi:10.1002/joc.3711

Other observational datasets

- **GPCC Global Precipitation Climatology Centre** dataset. Monthly gridded precipitation dataset at 0.5° spatial resolution.

- **GPCP Global Precipitation Climatology Project** dataset. Monthly analysis of surface precipitation from 1979-present at 2.5° spatial resolution, based on a combination of satellite and gauge measurements.

- **MERRA** (Modern-Era Retrospective analysis for Research and Applications) dataset. NASA reanalysis, performed at a horizontal resolution of 0.66° x 0.5° for temperature, precipitation, cloudiness and pressure.

- **UDEL** University of Delaware gridded dataset (http://www.esrl.noaa.gov/psd/), which is a monthly climatology (air temperature and precipitation) at horizontal resolution of 0.5° spanning 1901 to 2010, obtained putting data together from a large number of stations.

- **TRMM** Tropical Rainfall Measuring Mission. Provides global daily precipitation estimates from a wide variety of meteorological satellites at 0.25° spatial resolution

Problems of gridded dataset

Although gridded observational datasets are very useful and widely adopted to evaluate regional model performances, it must be taken into account that they can be affected by a number of potential inaccuracies.

- For example, typical error of E-OBS include incorrect station location and inhomogeneities in the station time series. The accuracy decrease in areas characterized by a low density of stations or in area with complex orography. In several works, E-OBS data have been analysed and assessed (e.g. Hofstra et al. 2009; Turco et al., 2013).

- When CRU and GPCC datasets are used to compare model results over MENA-CORDEX domain, it must be taken into account that the gauge network over this area is highly irregular (Bucchignani et al, 2015). Furthermore, satellite data (e.g. GPCP) tend to overestimate precipitation over semi-arid region of Africa (Panitz et al. 2014; Rosenfeld and Mintz 1988).

Bucchignani et al., 2015 "Sensitivity analysis with the regional climate model COSMO-CLM over the CORDEX-MENA domain." *Meteorol Atmos Phys* DOI 10.1007/s00703-015-0403-3

Hofstra et al., 2009 " Testing E-OBS European high-resolution gridded data set of daily precipitation and surface temperature". *J. Geophys. Res.* 114: D21101

Panitz et al., 2014 "COSMO-CLM (CCLM) climate simulations over CORDEX-Africa domain: analysis of the ERA-Interim driven simulations at 0.44 and 0.22 resolution ". Clim Dyn 42(11–12):3015–3038.

Rosenfeld and Mintz (1988) "Evaporation of rain falling from convective clouds as derived from radar measurements." *J Appl Meteorol* 27:209–215

Turco et al., 2013 "Assessing gridded observations for daily precipitation extremes in the Alps with a focus on northwest Italy. " *Nat. Hazards Earth Syst. Sci.*, 13, 1457–1468

Conclusions

• Simulations give a collective picture of a substantial drying and warming of the Mediterranean region, especially in the warm season (precipitation decrease exceeding –30% and warming exceeding 4° C).

•The only exception to this picture is an increase of precipitation during the winter over some areas of the northern Mediterranean basin.

•These signals are robust in that they are present in most projections from both global and regional models, and are consistent across emission scenarios and future time slices.

• Need for very high resolution simulations over the Mediterranean area.

• Data quality must be carefully evaluated: uncertainty and sensitivity.

Thanks

cmcc
Centro Euro-Mediterraneo sui Cambiamenti Climatici