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ASSESSMENT OF REGIONAL EXPERIENCE ON CLIMATE VARIABILITY AND CHANGE MONITORING AND PREDICTIONS IN THE MEDITERRANEAN AREA

Strategic Partnership for the Mediterranean Sea Large Marine Ecosystem
MedPartnership

Together for the Mediterranean Sea

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ASSESSMENT OF REGIONAL EXPERIENCE ON CLIMATE VARIABILITY AND CHANGE MONITORING AND PREDICTIONS IN THE MEDITERRANEAN AREA

Technical Report

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Euro-Mediterranean Center for Climate Change
Centro Euro-Mediterraneo per i Cambiamenti Climatici

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ABSTRACT

In the context of the preparation of the UNEP/MAP project ***"Integration of climatic variability and change into national strategies to implement Integrated Coastal Zones Management (ICZM) Protocol in the Mediterranean"***, this technical report is aimed at providing preliminary information and data on climate variability and change over the region as well as at recommending new possible common activities to meet the objectives of the project.

The report initially presents and discusses a short overview of the main features of the Mediterranean basin climate and its possible changes as obtained from future projections. From a number of numerical climate simulations performed in a variety of research projects, the Mediterranean region appears to be prone to substantial possible changes. A remarkable increase of the surface temperature and a reduction of the precipitation might affect the whole region and especially its hydrologic cycle during summer. According to the most recent climate projections performed in the framework of the CIRCE EU Project, the sea level rise of the Mediterranean Sea due to the steric effect ranges between +6.6 cm and +11.6 cm, with respect to the reference period 1961-1990.

Secondly, an overview of regional climate monitoring programmes in the Greater Mediterranean Region is presented. It highlights a number of relevant observing programmes and networks involving Mediterranean and North African countries, along with related data archives. National assessments have been also carried out, revealing the absence of specific national programmes for monitoring climate variability and change, and the general inadequacy of systematic observation networks as well as relevant database in many Mediterranean countries. Possible regional activities have been proposed to overcome the identified gaps.

Furthermore, an introductory overview of existing observational and gridded datasets and climate modelling in the Mediterranean region is presented. In this context, the innovative characteristics of CIRCE models are shown to allow a more detailed investigation of Mediterranean climate variability and change, due the realistic representation of the Mediterranean Sea in the models. Indications for new activities to further improve modelling for the Mediterranean region are subsequently proposed.

The paper continues with a general analysis of the different types of indicators suitable for climate studies in the Greater Mediterranean Region along with an overview of the most recent

ones used for this purpose. A detailed review of the data sources and data sets available over the Mediterranean for the development of climatic descriptive indicators has been carried out and potential indicators are proposed accordingly.

Finally, the need for a training programme on climate change issues is addressed and a proposal for fellowship and exchange activities aimed at strengthening national scientific capacities and improving regional coordination in the Mediterranean area is presented.

As a conclusion, a set of key recommendations have been identified for (i) improving the climate modelling of the Mediterranean area, (ii) supporting the full implementation of regional systematic observation activities and enhancing national capacities for climate monitoring, (iii) enhancing the indicators-based studies over the Mediterranean area and (iv) supporting training activities.

ACRONYMS

ALT	Altimeter Calibration
AMS	Automated weather stations
CBS	Commission for Basic Systems
CCR	Regional Climatological Centre / Centre Climatologique Régional (Algeria)
CCV	Climate Change and Variability (indicators)
CGCM	Coupled General Circulation Model
CIESM	The Mediterranean Science Commission / Commission Internationale pour l'Exploration Scientifique de la Mer Mediterranée
CIRCE	Climate Change and Impact Research: the Mediterranean Environment (EU Project)
CLIPS	Climate Information and Prediction Services
CoRI	Coastal Research Institute (Egypt)
CMCC	Euro-Mediterranean Center for Climate Change / Centro Euro-Mediterraneo per i Cambiamenti Climatici (Italy)
COP	Conference of the Parties to the UNFCCC
CRTS	Centre Royal de Télédétection Spatiale (Morocco)
CVIs	Coastal Vulnerability Indices
DABLAS	Danube-Black Sea Programme
DARE&H	Data Rescue and Homogenisation
DCP	Data Collecting Platform
DGH	Direction Générale de l'Hydraulique (Morocco)
DPSIR	Drivers/Pressures/State/Impacts/Response framework
DMN	Direction de la Météorologie Nationale (Morocco)
DWD	Deutcher Wetterdienst (Germany)
EA/WRUS	East Atlantic/Western Russia pattern
ECA&D	European Climate Assessment & Data set
ECMWF	European Centre for Medium-term Weather Forecasting
ECOOP	European COastal sea Operational observing and Forecasting system (EU Project)
ECVs	GCOS Essential Climate Variables
EEAA	Egyptian Environmental Affairs Agency (Egypt)
EIMP	Environmental Impact Monitoring Programmes
EGO	European Gliding Observatories
ESEAS	European Sea Level Service
ESONET	European Seas Observatory Network
EMSO	European Multidisciplinary Seafloor Observatory
ENSO	El Niño Southern Oscillation

EPA	Environmental Protection Agency (USA)
ePA	environmental Protection Agency (Montenegro)
EU	European Union
EUMETNET	Network of European Meteorological Services
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EuroARGO	European contribution to ARGO programme (EU Project)
EuroSITES	European Ocean Observatory Network (EU Project)
FRIEND	Flow Regimes from International Experimental and Network Data
GDP	Gross Domestic Product
GHCN	Global Historical Climatology Network
GIS	Geographic Information System
IAEA	International Atomic Energy Agency
IEWE	Institute of Energy, Water and Environment (Albania)
ICPDR	International Commission of Protection of the Danube River
ICSU	International Council of Science
ICZM	Integrated Coastal Zone Management
IGBP	International Geosphere-Biosphere Project
IGSR	Institute of Graduate studies and Research (Egypt)
INFO/RAC	Regional Activity Centre on Information of UNEP/MAP
INGV	National Institute of Geophysics and Volcanology / Istituto Nazionale di Geofisica e Vulcanologia (Italy)
IOC	International Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
IRIMO	Iranian Meteorological Organization (Iran)
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
JMA	Japan Meteorological Agency
LTT	Long Term Trends
G3OS	The three Global Observing Systems
GAW	Global Atmosphere Watch
GCM	General Circulation Model
GCN	GLOSS Global Core Network
GCOS	Global Climate Observing System
GEF	Global Environment Facility
GEMS	Global Environment Monitoring Centre on Water Quality
geoland2	Operational Monitoring Services for our Changing Environment (EU Project)
GEOSS	Global Earth Observation System of Systems
GEWEX	Global Energy and Water Cycle Experiment
GLOSS	Global Sea-Level Observing System

GMES	Global Monitoring for Environment and Security
GMR	Greater Mediterranean Region
GNIP	Global Network of Isotopes in Precipitation
GOS	Global Observing System
GOSIC	Global Observing System Information Centre
GOOS	Global Ocean Observing System
GPCC	Global Precipitation Climatology Centre
GRA	GOOS Regional Alliances
GRDC	Global Runoff Data Centre
GSN	GCOS Surface Network
GSNMC	GSN Monitoring Centre
GT-NET	Global Terrestrial Observing Network
GTN-G	Global Terrestrial Network on Glaciers
GTN-H	Global Terrestrial Network on Hydrology
GTN-L	Global Terrestrial Network on Lakes
GTN-P	Global Terrestrial Network on Permafrost
GTN-R	Global Terrestrial Network on River Discharge
GTOS	Global Terrestrial Observing System
GUAN	GCOS Upper-Air Network
M3A	Mediterranean Moored Multi-sensor Array
MACC	Monitoring Atmospheric Composition and Climate (EU Project)
MATE	Ministry for Land Management and Environment / Ministère de l'Aménagement du Territoire et de l'Environnement (Algeria)
MCS	GMES Marine Core Service
MED POL	Marine pollution assessment and control component of MAP
MEDARE	WMO Initiative on Mediterranean Climate Data Rescue
MedARGO	ARGO programme in the Mediterranean
MedGLOSS	Monitoring Network System for Systematic Sea Level Measurements in the Mediterranean and Black Sea
MedGOOS	Mediterranean Global Ocean Observing System
MED-HYCOS	Mediterranean Hydrological Cycle Observing System
MOON	Mediterranean Operational Oceanography Network
MyOcean	Ocean Monitoring and Forecasting (EU Project)
MFS	Mediterranean Forecasting System
MSLP	Mean Sea Level Pressure
MTHC	Mediterranean Thermohaline Circulation
NAO	North Atlantic Oscillation
NCDC	National Climatic Data Center (USA)
NEAP	National Environment Action Plan (Bosnia and Herzegovina)
NFP	GCOS National Focal Point

NIM	National Institute of Meteorology (Tunisia)
NIOF	National Institute of Oceanography and Fisheries (Egypt)
NMHSs	National Meteorological and Hydrological Services
NOAA	National Oceanic and Atmospheric Administration (USA)
NRT	Near Real Time
OC	Ocean Circulation
ONEDD	National Observatory of Environment and Sustainable Development / Observatoire National de l'Environnement et du Développement Durable (Algeria)
ONM	National Meteorological Office / Office National de la Météorologie (Algeria)
ONS	National Droughts Observatory / Observatoire National de la Sécheresse (Morocco)
OSS	Sahara and Sahel Observatory
PMO	Palestinian Meteorological Office (Palestinian Authority)
PPG	GEF Project Preparation Grant
PSMSL	Permanent Service for Mean Sea Level
PWA	Palestinian Water Authority (Palestinian Authority)
RBCNs	Regional Basic Climatological Networks
RBSNs	Regional Basic Synoptic Networks
RCM	Regional Climate Model
REReP	Regional Environment Reconstruction Programme for South Eastern Europe
ROSELT	Long-term Ecological Monitoring Observatories Network / Réseau d'Observatoires de Surveillance Ecologique à Long Terme
SAFs	EUMETSAT Satellite Application Facilities
SESAME	Southern European Seas: Assessing and Modelling Ecosystem changes (EU Project)
SLP	Sea-Level Pressure
SOOP	Ship Of Opportunity Programme
SRES	IPCC Special Report on Emission Scenarios
SST	Sea Surface Temperature
T2m	2-metre temperature
TOPC	Terrestrial Observation Panel for Climate
UNFCCC	United Nations Framework Convention on Climate Change
UNEP/MAP	United Nations Environment Programme/Mediterranean Action Plan
UNESCO	United Nations Economic, Social and Cultural Organization
VOS	Voluntary Observing Ship
WCRP	World Climate Research Programme
WCDMP	World Climate Data and Monitoring Programme
WDCA	World Data Centre for Aerosols

WDCPC	World Data Centre for Precipitation chemistry
WDCGG	World Data Centre for Greenhouse Gases
WHYCOS	WMO World Hydrological Cycle Observing System
WIGOS	WMO Integrated Global Observing System
WMO	World Meteorological Organization
WOUDC	World Ozone and Ultraviolet Radiation Data Centre
WRDC	World Radiation Data Centre
WWW	WMO World Weather Watch Programme

1 INTRODUCTION

1.1 Background

The Protocol on Integrated Coastal Zone Management (ICZM) of the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention) was adopted in Madrid on 21 January 2008.

The ICZM Protocol is the seventh Protocol in the framework of the Barcelona Convention and represents a crucial milestone, since it completes the set of Protocols for the Protection of the Marine Environment and the Coastal Mediterranean Region. It will allow the Mediterranean countries to better manage and protect their coastal zones, as well as to deal with the emerging coastal environmental challenges, such as the climate change.

One of the objectives of the integrated coastal zone management approach, as indicated at Art.5 of the ICZM Protocol is: ***<<prevent and/or reduce the effects of natural hazards and in particular of climate change, which can be induced by natural or human activities>>.*** According to Art.22 of the Protocol Parties *<<shall develop policies for the prevention of natural hazards. To this end, they shall undertake vulnerability and hazard assessments of coastal zones and take prevention, mitigation and adaptation measures to address the effects of natural disasters, in particular of climate change>>*.

Furthermore, the governments are committed under the United Nations Framework Convention on Climate Change (UNFCCC) to cooperate for the development of appropriate and integrated plans for coastal zone management pursuant to UNFCCC Art. 4 paragraph 1(e).

In this context, and within the framework of the Project Preparation Grant (PPG) of the Global Environment Facility (GEF), UNEP/MAP (United Nations Environment Programme - Mediterranean Action Plan) is preparing a full-size project named ***"Integration of climatic variability and change into national strategies to implement ICZM Protocol in the Mediterranean"***. The objective of the project is to **support the implementation of the ICZM Protocol through the development of region-wide coordination mechanisms and tools to address climate variability and change.**

To achieve its outcomes the project foresees the implementation of four components:

1. **Development of regional climate variability monitoring programme**, which will be:
   - Supported by a web-based regional data platform on climate research;

- Linked with other data platforms, including MAP's Regional Activity Centre on Information (INFO/RAC);
- Integrated along with the database into national and regional ICZM monitoring processes.

2. **Strengthening of knowledge base** by:
   - Ensuring that current models assessing scenarios and impacts of climate variability are applied to the region;
   - Assisting countries to more precisely calculate the impacts of climate variability to their marine and coastal zone;
   - Focusing on the coastal watersheds, with emphasis on risks to water availability and quality and marine ecosystems (including agriculture and fisheries), and other risks such as coastal erosion and landslides.
3. **Strengthening partnerships, capacity and exchange for implementation of the ICZM Protocol** in order to enable stakeholders to:
   - Conduct at the national level, inter-ministerial committees which will contribute to multi-sectoral dialogues on policy and management processes in the Mediterranean, and facilitate the mainstreaming of the ICZM protocol into national plans;
   - Create regionally strong platforms for exchange and sharing project experiences within the larger international waters community.
4. **Project Management**.

The project involves the possible participation of the following GEF eligible countries: Albania, Algeria, Bosnia and Herzegovina, Croatia, Egypt, Libya, Morocco, Montenegro, Syria, Tunisia and the Palestinian Authority.

1.2 Aim and scope of the technical report

In support of the UNEP/MAP efforts for the preparation of the aforementioned project proposal, the Euro-Mediterranean Center for Climate Change (CMCC) was requested to perform a regional assessment on experience on climate variability and change monitoring and prediction, existing data, gaps, and on needs for the improvement of national capacity within the Mediterranean region. The resulting technical report is aimed at providing preliminary information

and data to the preparation of the full-size project document as well as recommending possible new common activities. The CMCC shall ensure that those are considered in the development of the project proposal.

In order to achieve such objectives, the following activities have been and shall be undertaken:

- Analysis of the state of climate variability and climate change phenomena within the Mediterranean region;
- Preliminary analysis of existing programme(s) for monitoring climate variability and change, relevant data base, and proposal of activities related to a Regional Data Base and a Regional Monitoring Programme;
- Preliminary analysis of existing models for climate variability and change prediction and existing data, and proposal of activities concerning modelling;
- Preliminary analysis of in-use indicators for climate variability and change monitoring and predictions;
- Proposal of relevant training programme at national and regional level;
- Attendance at the Steering Committee meeting to discuss the draft project document;
- Assistance in drafting the project document for the full-size project.

2 ANALYSIS OF CLIMATE VARIABILITY AND CHANGE WITHIN THE MEDITERRANEAN REGION

The climate of the Mediterranean region, i.e. the region comprising the Mediterranean Sea and the surrounding areas in Europe, North Africa and Asia, is determined by the interaction between mid-latitude weather regimes, sub-tropical processes and the complex morphology (mountain chains and land-sea contrasts) that characterizes this part of the Earth.

The Mediterranean region has been identified as one of the main climate change "hot spots" (Giorgi, 2006), i.e. one of the most responsive areas to climate change. Moreover, this area is populated by over 500 million people, collected in about 30 countries in Africa, Asia and Europe, making it one of the most interesting case studies from the scientific point of view and important from a social perspective.

2.1 The climate of the Mediterranean region

A main characteristic of the Mediterranean is the high spatial variability in seasonal mean temperature and total precipitation, enhanced by the complex orography. Figure 2.1 shows the seasonal means of near-surface temperature (panels a and c) and total precipitation (panels b and d) as obtained from an observational data set (CRU-TS.3) (Mitchel and Jones, 2005) for the period 1971-2000. The Mediterranean mean winter (December-January-February) temperature exhibits patterns with high spatial variability, ranging from the cold values that characterize the mountain areas of the northern part of the region (Pyrenees, Alps, Dinaric Alps and Anatolian Highlands) to the mild areas of the coastlines and of the southern shores. In summer (June-July-August), the mean 2-metre temperature (T2m) shows a marked meridional gradient from the cooler (~15°C) northern areas to the hot southern part of the basin, where near-surface temperature easily exceeds 25°C.

The mean winter precipitation (Figure 2.1, panels b and d) amounts range from less than 1-1.5 mm/day (North Africa, south-eastern of the Iberian Peninsula, eastern Balkans and Central Anatolia) to over 4-5 mm/day (along western coasts of the peninsulas and over the Alpine region amplified by the orographic forcing). In summer, the total precipitation is substantially reduced over most part of the basin and surrounding areas. Over North Africa, Middle East and over the

southern part of Spain, Italy, Greece and Turkey, seasonal mean precipitation is generally lower than 0.8 mm/day. Over the mountainous regions extending from southern France to western Balkans, on the other hand, precipitation increases in this season, exceeding 6 mm/day over the western and central Alps.

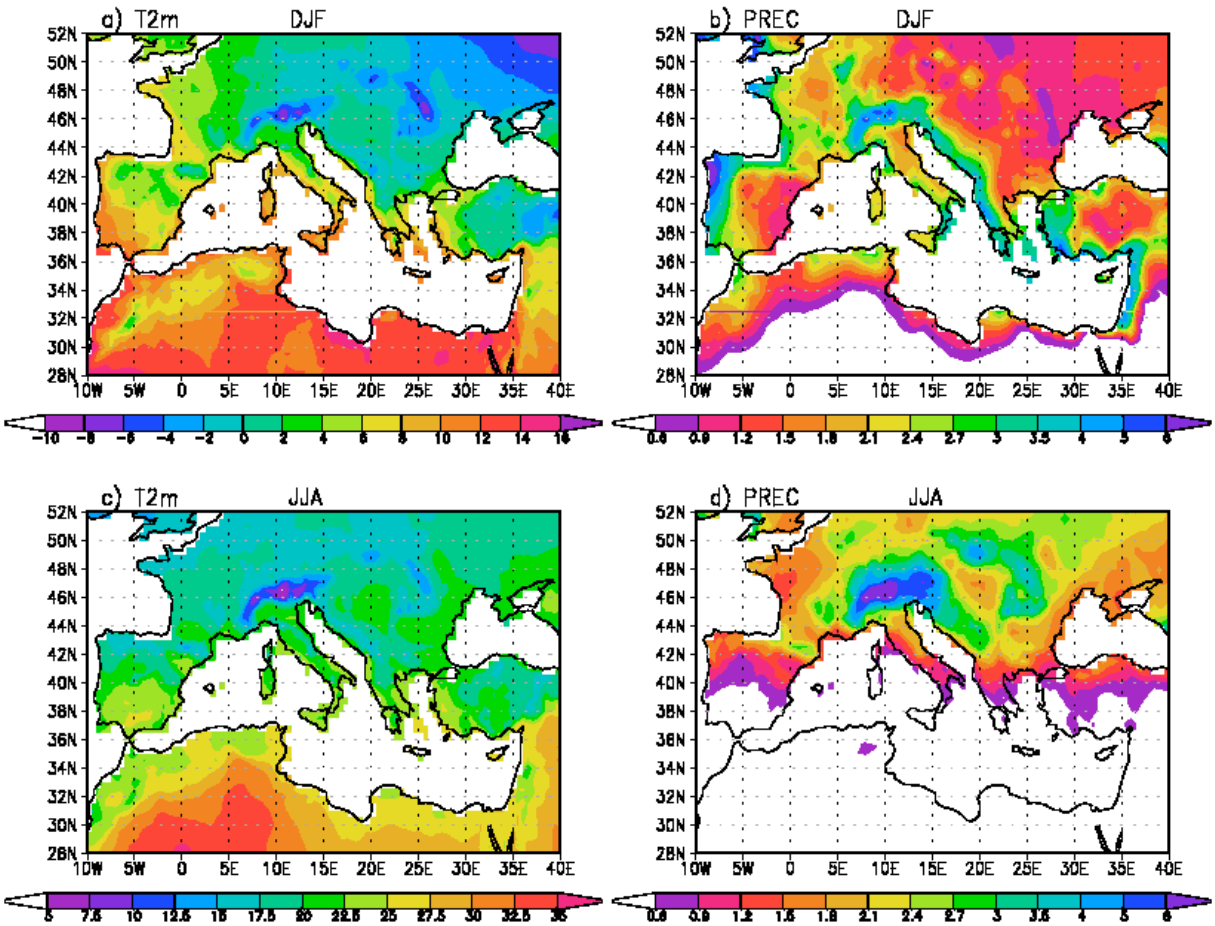

Figure 2.1: mean 2-metre Temperature (left panels) and mean precipitation (right panels) as obtained from the CRU-TS.3, Mitchel and Jones (2005) observational data set for the 1971-2000 period. Upper panels show the winter means (December-February). Lower panels show the summer means (June-August). Temperature units are °C; precipitation units are mm/day.

During winter, the western Mediterranean is influenced by a mid-tropospheric northwesterly flow, associated with moisture transport from the North Atlantic (not shown). Over the eastern basin a mid-tropospheric westerly flow is prevalent. In summer, the atmospheric circulation over the basin is characterised by weak gradients and generally reduced circulation variability. The northward shift of the subtropical ridge that leads to enhanced stability over the entire area, and the expansion of the subtropical anticyclone from the Atlantic to the western and central Mediterranean dominate the surface circulation. The thermal low-pressure system, which

is located over the Arabian Peninsula and expands towards the eastern Mediterranean, is linked to the Asian summer monsoon (Zhang et al. 2004).

A key feature for the climate of the Mediterranean region is the presence of the Mediterranean Sea itself. The basin, in fact, represents an important source of energy and moisture to the atmosphere. The local evaporation largely exceeds precipitation during all seasons and the characteristics of the local water budget influence the amount of moisture available for the neighbouring land regions, especially northeast Africa and the Middle East. Sea Surface Temperature (SST) anomalies govern, at least in part, air temperature and precipitation anomalies in the surrounding land areas.

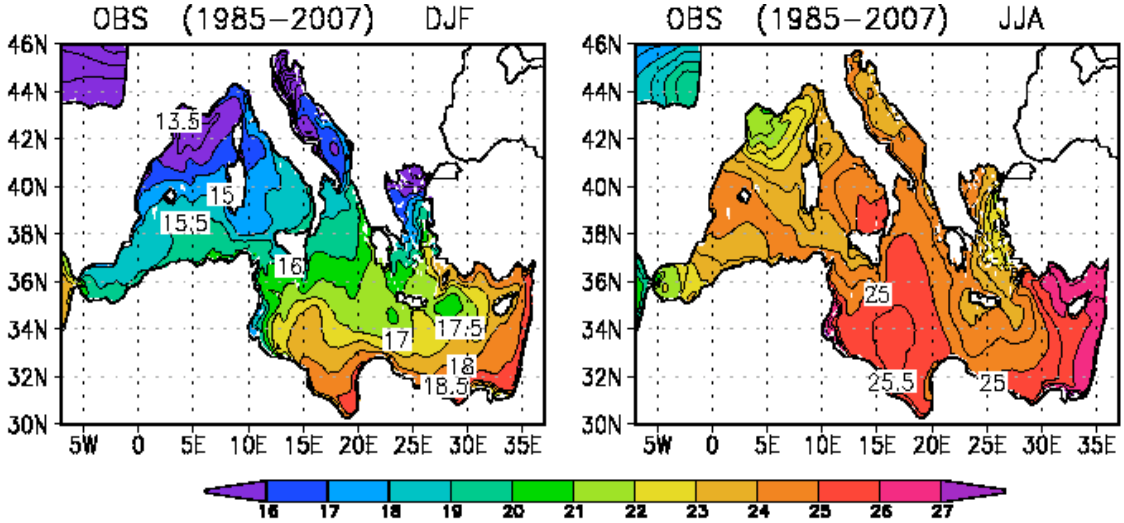

Figure 2.2: seasonal means of the Mediterranean Sea-Surface Temperature (SST) obtained from ocean re-analyses (Adani et al. 2010) for the period 1985-2008). Left panel shows the winter (December-February) mean; right panel shows the summer (June-August) mean. Units are in °C.

The Mediterranean SST pattern (Figure 2.2) shows a predominant northwest – southeast gradient with a warmer eastern and a cooler western basin. This large-scale structure, however, exhibits some large sub-regional modification, principally associated with the local nature of atmospheric fluxes, wind system and the oceanic circulation. In the winter season (Figure 2.2, right panel), the SST ranges between about 13° to 19°C. The lowest SSTs are found in the Gulf of Lions, the northern Adriatic Sea (13° C) and the Black Sea (10° C, not shown in Figure 2.2). In summer (right panel), the observed SST is in the 20° to 26°C range, with cooler surface water in the Gulf of Lions and in vicinity of the Strait of Gibraltar. The warmest SST is found in the eastern basin.

The low pressure systems travelling from the Atlantic Ocean and moving across the basin are regenerated above the warmer Mediterranean SSTs and precipitate over the western coasts of the peninsulas as shown in Figure 2.1.

2.2 Climate variability in the Mediterranean region

The temperature and precipitation mean patterns shown in Figure 2.1 and 2.2 show also some substantial variability at interannual and decadal timescales. The temperature variability (e.g. the standard deviation of the monthly means for the 1971-2000 period, not shown) is generally larger during the winter season, with maxima of about 2°C over the Anatolian Peninsula, Balkans and northern Italy. In summer, the deviation from the seasonal mean temperature is generally smaller than 1°C over large part of the region.

For precipitation, the areas with the higher seasonal mean values are also the locations where the variability is higher, especially at interannual time scales, both in winter and in summer. Noteworthy, the lower station density over areas with complex topography, as for example the Alpine regions, is generally related with an underestimation of precipitation variability.

Figure 2.3 shows the time series of the 2-metre temperature (upper panel) and precipitation (lower panel) annual mean anomalies averaged over the land surrounding the Mediterranean basin (10°W-40°E ; 30°N-48°N) observed during the 20th century (Mitchel and Jones, 2005).

The evolution of T2m shows some clear evidence of the warming trend observed during the past century, with the temperature anomalies systematically colder than average during the early part of the time series, whereas warm anomalies are clearly predominant in the last part of the considered period. Beside the general warming tendency, both the annual mean T2m and precipitation anomalies show a substantial variability that ranges from interannual to decadal time scales. This variability might alter quite substantially the mean seasonal conditions in the area, producing some relevant impacts. The prolonged negative anomalies of precipitation observed, for example, during the second half of the 1940s or during the 1980s and early 1990s have induced reduced water availability and drought conditions over large part of the region.

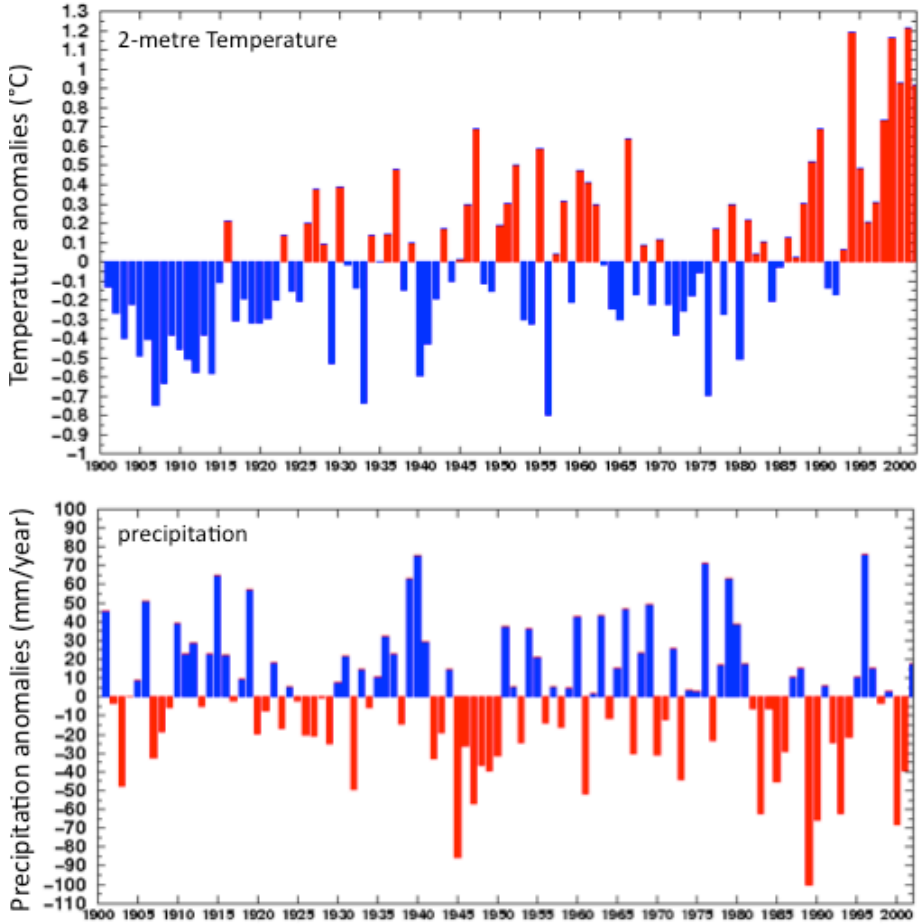

Figure 2.3: evolution of the 2-metre temperature (T2m) and precipitation annual mean anomalies over land in the Mediterranean basin observed during the 20th century (Mitchel and Jones, 2005). The land T2m and precipitation have been averaged over the area (10°W-40°E ; 30°N-48°N).

High variability characterizes also the mean sea-level pressure (SLP) field. In the western Mediterranean, the SLP variability appears to be linked with the well-known dipole structure over the North Atlantic that characterizes the North Atlantic Oscillation (NAO) (Hurrell et al., 2006). Other centres of SLP variability are associated with the cyclogenetic areas. The physiography of the region, in fact, with its complex topography that steers the air flow and the Mediterranean basin that acts as a heat and moisture source, provides favourable conditions to the development of intense atmospheric mesoscale phenomena, which can in turn evolve into extreme weather events, such as cyclones, strong wind storms and heavy precipitation systems.

The low pressure disturbances that generate over the North Atlantic, moving then through the Mediterranean, and the cyclogenetic activity of areas such as the lee of the Alps, the Gulfs of Lions and Genoa, the Aegean Sea and the Cyprus area among others, influence the winter climate variability of the region (Lionello et al., 2006; Xoplaki, 2002).

2.3 The links with the global climate system

Beside the small scale, local processes driven and modulated by the orographic forcing and by the land-sea contrast, the Mediterranean climate is influenced by the large scale circulation, connecting the basin with both tropical and mid-latitude climate dynamics (Trigo et al., 2006; Barry and Chorley, 2003; and references therein). Several studies have investigated the relationship between the Mediterranean climate variability and the large-scale atmospheric circulation modes in the Northern Hemisphere (e.g., Toreti, 2010 and references therein; Xoplaki et al. 2004, 2003; Dünkeloh and Jacobeit, 2003; Jones et al. 2003; Quadrelli et al., 2001; Hurrell and van Loon, 1997; Corte-Real et al., 1995; among others). During winter, the most relevant atmospheric circulation modes for the Mediterranean region are the North Atlantic Oscillation (NAO), the East Atlantic pattern, the East Atlantic/Western Russia pattern (EA/WRUS) and the Scandinavian pattern (Barnston and Livezey, 1987). In this season, the Mediterranean precipitation appears to be significantly correlated with the NAO signal (Xoplaki et al., 2004), especially in the western basin (Trigo et al., 2004).

At the same time, there are evidences that the Mediterranean climate variability is statistically linked also to the El Niño Southern Oscillation (ENSO) and the South Asian Monsoon (Alpert et al., 2006). In particular, ENSO appears to be connected with fluctuation of rainfall in Israel, with increased precipitation found during the positive phase of the oscillation (Price et al., 1998; Yakir et al., 1996) and to monthly precipitation variability over Turkey (Kadioglu et al., 1999). Furthermore, Mariotti et al. (2002) found a significant correlation between ENSO and autumn precipitation in the western Mediterranean. In a similar study, Brönnimann et al. (2007) found temperature and precipitation anomalies over Europe in winter, which seem to be associated with the El Niño events. However, it is important to note that the relationship between ENSO and the Mediterranean climate appears to be highly nonlinear and not stable because of the many processes and of the natural noise (high-frequency variability) that can alter the connection between the Mediterranean and the tropical Pacific regions. Finally, Rodwell and Hoskins (1996) and Ziv et al. (2004) identified and analyzed a possible connection between summer regimes in the eastern Mediterranean and the Asian Monsoon system.

2.4 The Mediterranean climate change observed during the past decades

Using both gridded and station data, Ulbrich et al. (2011) assessed the Mediterranean past and recent trends (1951-2005) of seasonal (winter, December-January-February and summer, June-July-August) temperature and precipitation, using nonparametric and robust statistical tools. According to their results, winter precipitation in the Mediterranean is characterized by a drying during the past decades.

Observational data sets (CRU-TS.3) (Mitchel and Jones, 2005) reveals that the near-surface temperature is characterized by a significant increasing trend over the western Mediterranean, especially over the Iberian Peninsula and France. A remarkable cooling, on the other hand, is found over the southern Balkans and Turkey. In contrast, other data sets based on station series do not show statistically significant changes for the winter temperature, except for few sites over northern Italy.

A strong and statistically significant increase of mean summer temperature is identified for both gridded (CRU-TS.3) and station data (Ulbrich et al. 2011). However, over Turkey the temperature trend from gridded data is weaker than the one estimated from the station time series.

For summer precipitation (not shown), large areas, as the Iberian Peninsula and northern Italy and the Alpine areas, reveal a statistically significant decreasing trend. The observed differences in statistical significance between the gridded and station data could be related to the quality of the station time series (e.g., time continuity) and/or to the fact that gridded data are derived with a procedure optimized in space rather than in time (Mitchell and Jones, 2005).

Consistent with the temperature and precipitation, also the mean sea-level pressure (SLP) field presents statistically significant trends during the period 1951-2005 (not shown). In particular, the winter SLP field presents a strong positive trend over the Atlantic and the Mediterranean area, with highest values over Western Europe and the Mediterranean. In summer, an area with weaker but positive trend appears to characterize the whole Mediterranean region, most parts of Europe, the Middle East and North Africa.

These results highlight a changing atmospheric circulation over the Mediterranean, leading to a northward shift of the Atlantic storm track and an increased stability over the basin. Giorgi and Lionello (2008) found similar results in a study based on global model simulations.

The Mediterranean SST trends obtained from ocean re-analyses (Adani et al., 2010) are in good agreement with the seasonal air temperature of the surrounding land areas. Increasing SSTs for both seasons are detected in the central and western Mediterranean, with the exception of the Ligurian Sea. In winter, significant downward trends are identified in the Eastern Mediterranean and the Black Sea.

2.5 Climate simulations and climate change projections for the Mediterranean region

In the recent past, a number of scientific initiatives and projects have been undertaken to assess the possible changes that anthropogenic global warming might induce in the climate of the European continent and in the Mediterranean area. Specifically, scenario simulations aimed at quantifying the possible future climate change in the European and Mediterranean region have been designed and performed in the framework of EU Projects as PRUDENCE (Christensen and Christensen, 2007) or ENSEMBLES (Christensen et al., 2009). At the same time, coordinated studies have investigated and discussed the climate change signal in the Mediterranean region projected by both regional climate models (RCMs) and global climate models (GCMs) (e.g. Giorgi and Lionello, 2008). On the same line, Marcos and Tsimplis (2008) used data from the CMIP3 (Coupled Model Inter-comparison Project 3) (Meehl et al., 2007) GCMs to assess the uncertainty range of the response of the Mediterranean temperature, salinity and sea level change along the 21st century. They mainly demonstrated that, because of their low spatial resolution, the CMIP3 GCMs are not able to simulate a realistic Mediterranean Sea in present climate and that their climate change results are consequently doubtful.

Box 2.1: CMIP3 (Coupled Model Intercomparison Project)

In response to a proposed activity of the *World Climate Research Programme (WCRP) Working Group on Coupled Modelling (WGCM)*, the *Programme for Climate Model Diagnosis and Intercomparison (PCMDI)* volunteered to collect model output contributed by leading modeling centres around the world. Climate model output from simulations of the past, present and future climate was collected by PCMDI mostly during the years 2005 and 2006, and this archived data constitutes phase 3 of the *Coupled Model Intercomparison Project (CMIP3*).

This unprecedented collection of recent model output is officially known as the "**WCRP CMIP3 multi-model dataset**". It is meant to serve IPCC's Working Group 1, which focuses on the physical climate system - atmosphere, land surface, ocean and sea ice - and the choice of variables archived at the PCMDI reflects this focus. A more comprehensive set of output for a given model may be available from the modelling centre that produced it. With the consent of participating climate modelling groups, the WGCM has declared the CMIP3 multi-model dataset open and free for non-commercial purposes.

As of July 2009, over 36 terabytes of data were in the archive and over 536 terabytes of data had been downloaded among the more than 2500 registered users.

Here we will discuss mainly the climate simulations performed within the EU Project CIRCE (Navarra et al., 2011) and will compare these results with the findings obtained from previous simulations (e.g. PRUDENCE and CMIP3). Within CIRCE a new set of climate models have been developed specifically designed to perform climate simulations and projections with a focus on the Mediterranean region. These models (hereafter referred to as CIRCE models) and the simulations performed with them (CIRCE simulations) represent a substantial improvement in the representation of the Mediterranean Sea in the system (see Chapter 4 of the present report for more details).

Box 2.2: The Project CIRCE - Climate Change and Impact Research: the Mediterranean Environment

CIRCE is an FP6 EU Integrated Project Coordinated by A. Navarra (CMCC, Italy) and L. Tubiana (IDDRI, France) during 3007-2011.

CIRCE studies the climate change in the Mediterranean not only in regard to scientific data but also in connection with economic and social impacts.

CIRCE, for the first time, studies the Mediterranean climate through a multi-disciplinary scientific staff to evaluate the best strategies of adaptation to climate change in the Mediterranean.

In **CIRCE**, the role of public engagement is fundamental, especially at the local level. To this aim, 11 case studies and specific participative methods have been designed.

The **CIRCE** final product is a Regional Assessment of Climate Change in the Mediterranean (RACCM) produced together with stakeholders, as support system to the adaptation and mitigation policies in the Mediterranean region.

Despite the improved modelling of the Mediterranean Sea in the CIRCE models, the simulation of some observed features appears to remain problematic. The CIRCE models reproduce the observed patterns of orographic precipitation over the northwest of the Iberian Peninsula, Alpine region, western coast of the Balkans and southwest Anatolian Peninsula. However, the systematic errors remain substantial, both in terms of T2m and precipitation.

During both the winter and summer seasons, the models are generally colder than observations by about 2°C over most of the region, but a larger error is found locally in the northern foothills of the Alps (almost -6°C), whereas a warm bias (~+4°C) covers the south-eastern part of the Alpine region, extending to the Croatian coast. This error might be due to a shift of the cooler temperatures associated with a mismatch of the location of the highest alpine elevations. In terms of precipitation, the CIRCE models produce an excess of precipitation over central Europe in both seasons and a lack of precipitation in the Alpine region, Middle East and, in summer, in the area of the Black Sea.

A pronounced cold bias relative to the observations is found also for the simulated sea surface temperature (SST) of the Mediterranean Sea. Despite this systematic error, most of the CIRCE models reproduce a realistic structure of the SST patterns and, in particular, of the observed SST gradients. Also the amplitude of the multiannual (interannual and decadal) variability appears to be reasonably well captured by the models, with maximum values of about 1°C.

A warmer and drier Mediterranean Region

Both in the CMIP3 and in the CIRCE simulations, the evolution of the modelled near-surface temperature averaged over the Mediterranean land during the recent past is in substantial agreement with the observations. In particular, they show that the region surrounding the Mediterranean Sea has been warming during most of the 20th century, especially during the period 1951-2000, when the warming trend is of about 0.1 °C/decade.

According to the CIRCE results, the warming is found to have a remarkable spatial and seasonal modulation (Figure 2.4, left panels). During northern summer, the trend over western and central Europe appears to be larger than in the winter season. The largest trend (up to 0.2°C/decade) is found in summer over the Iberian Peninsula and western part of North Africa. Importantly, also the spatial distribution of the modelled trends found for the second half of the 20th century is consistent with the result obtained from the observations for the instrumental period 1951-2005 (Ulbrich et al., 2011).

For precipitation (not shown), the models appear to capture the negative trend over the Iberian Peninsula and central eastern Europe observed in summer, during the second half of the 20th century. However, some discrepancy is found during winter, when the CIRCE simulations, in contrast with the observations, produce some positive trend in southern Europe. The difficulties that the models appear to have in reproducing the decadal trends observed for precipitation

might be related to the marked decadal fluctuation that this parameter exhibits, mainly related to the large decadal variability that has characterized the NAO during the period 1951-2000 (Mariotti and Arkin, 2007). Therefore, the differences found between models and observations are most likely related to the different phases of the NAO low-frequency (decadal) variability in the simulations.

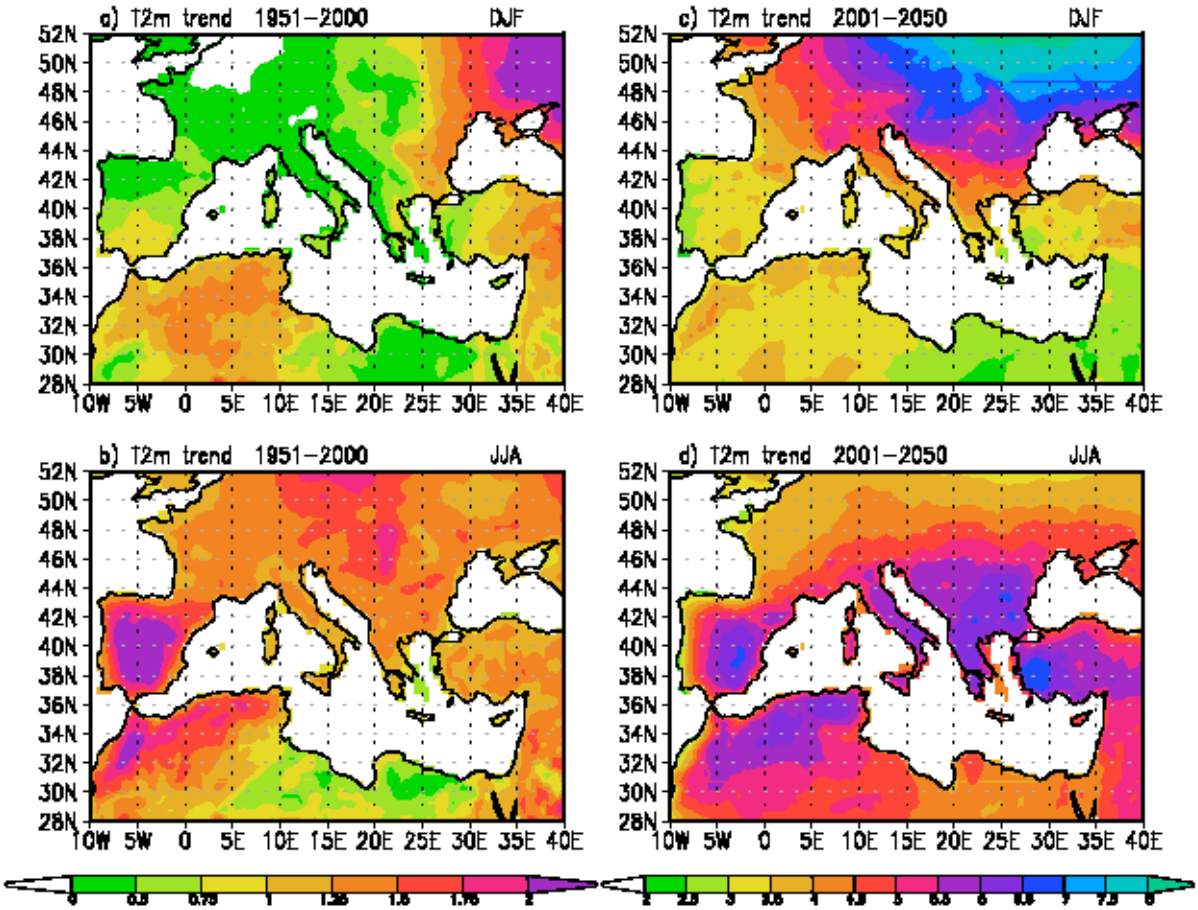

Figure 2.4: multi-model mean trend of the 2-metre temperature (T2m) obtained from the CIRCE simulations for the period 1951-2000 (left panels) and for the period 2001-2050 (right panels). Upper panels show the winter (DJF) case; lower panels show the summer (JJA) case. To facilitate the reading of the pictures, the plotted values are multiplied by a scale factor 10. Shaded contours are °C/decade.

During the projection period 2001-2050 (Figure 2.4, right panels), the simulated trends of the near-surface temperature appear to be much larger than in the reference period (1951-2000). In summer the simulated temperature might increase of more than 0.6°C/decade over large areas of the Mediterranean basin.

The trend towards a warmer and drier climate for the Mediterranean region in the next decades is consistent with the change in surface circulation suggested by the change in mean sea-

level pressure (SLP). In winter, a large area of increased SLP covers the entire Mediterranean region (not shown), which, thus, appears to be characterized by enhanced stability. Furthermore, the increased anti-cyclonic circulation associated with the enhanced Mediterranean surface pressure is associated with a northward shift of the Atlantic storm track. Both the increased stability and the northward displacement of the storm track have the effect to reduce the cyclonic activity in the Mediterranean basin which is consistent with the trend of reduced winter precipitation found in the projections.

More detailed information on the local characteristics of the projected changes in different sub-regions of the Mediterranean area has been provided in Giorgi and Lionello (2008) and Gualdi et al. (2011). A sub-regional detailing of the climate change response (Gualdi et al., 2011) shows that, though the increasing temperature is a robust feature of the whole Mediterranean region, the Alpine area appears to be more sensitive to global warming, especially during winter. Also the spread of the results obtained from the different models appears to be much larger in the Northern Mediterranean and in the Alps than in the western or central Mediterranean and in winter more than in summer.

The reduced summer rainfall is quite a homogeneous feature of the entire basin, even if the uncertainty due to the model spread is higher than for the near-surface temperature case. During winter, however, the precipitation response appears to be different in the northern part of the Mediterranean area and over the Alps, where some increase of rainfall is found, whereas the rest of the domain characterized by a pronounced tendency to reduced precipitation.

All these changes are consistent with the results obtained from other models and studies, such as the PRUDENCE climate change projections (Christensen and Christensen 2007) and the analysis that Giorgi and Lionello (2008) made of the CMIP3 simulations in the Mediterranean region. In all of these simulations, the changes in mean seasonal precipitation during northern winter are characterized by a relative small decrease in the whole Mediterranean basin (~ -5%), with almost no change in the northern part of the basin and a more visible reduction (~ -5%-10%) in the southern part. Interestingly, in the same season (winter), in all of the projections (CIRCE, PRUDENCE and CMIP3) the Alpine region appears to be affected by an increase in rainfall. During summer, all of the climate change projections show marked increase in the near-surface temperature and decrease in precipitation over the entire region.

Changes in the hydrologic cycle

The CIRCE projections for the 21st century, therefore, suggest that remarkable changes in the climate of the Mediterranean region might occur already in the next few decades, showing a substantially steadily increase of the near-surface temperature that leads the Mediterranean lands to be about 2°C warmer in the 2021-2050 period with respect to the 1961-1990 mean. The change in the simulated near-surface temperature is accompanied by a change in precipitation, with a clear tendency to dryer conditions for the Mediterranean area during both seasons and some tendency to increased winter precipitation over the Alpine region. These findings lead to suppose a more general alteration of the hydrologic cycle for the whole Mediterranean area.

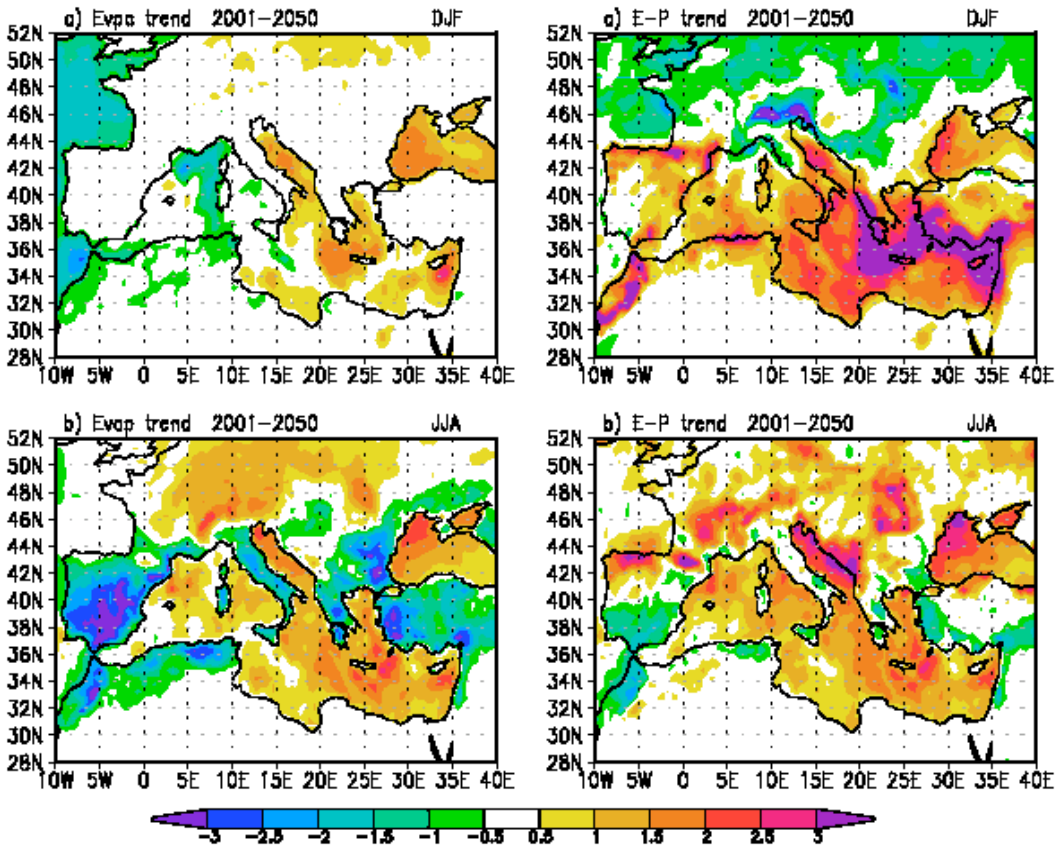

Figure 2.5: trends of evaporation (Evap, left panels) and evaporation minus precipitation (E-P, right panels) obtained from the CIRCE multi-model ensemble for the projection period 2001-2050 according to the A1B scenario. Upper panels show the trends for the winter season (DJF); lower panels show the summer season (JJA) results. Contours are (mm/month)/decade.

A first assessment of the impacts that climate change might have on the hydrologic cycle over the areas surrounding the Mediterranean Sea might be provided by an analysis of the change

in evaporation (E) and in the budget evaporation-precipitation (E-P). Figure 2.5 shows the trends of E (left panels) and E-P (right panels) obtained from the CIRCE models for the period 2001-2050. In winter, evaporation trend over the land is very small and, in general, not significant, whereas in summer (panel b) a large negative trend is found over the land areas surrounding the basin, especially in the Iberian Peninsula, Balkans and western Turkey. In this season, a positive trend appears to affect central Europe. Over the Mediterranean Sea (and Black Sea) according to the CIRCE projections, there is a pronounced tendency for increased evaporation, especially during summer in the eastern part of the basin.

The projected trend in the E-P budget (Figure 2.5, right panels) shows a clear and marked positive trend over the sea in both seasons due to the combined effects of increased evaporation and reduced precipitation (not shown). This result suggests a possible pronounced tendency of the basin to become more and more evaporative, in agreement with Mariotti et al. (2008). Interestingly, over the European continent the E-P trend has a seasonal character, with a predominantly negative trend during winter, especially in the Alpine region, and positive trends in summer.

Changes in the Mediterranean Sea water

In the period 2021-2050 the warming of the simulated SST (not shown) ranges between +0.8 °C and 1.8°C. For the sake of comparison, we recall that a value of +2.6°C was obtained in Somot et al. (2008) for year 2099 and SRES A2.

Box 2.2: IPCC SRES scenarios

Six emission scenarios are used for climatic simulations, based on the Intergovernmental Panel on Climate Change (IPCC) "*Special Report on Emission Scenarios*". They cover a large panorama of future key characteristics, such as demographic changes, economic development and technological change. No scenario is considered to be more probable than the others.

Scenarios A1 - Three scenarios are grouped into this family. They all describe a very rapid economic growth, a global population that platforms in 2050 and the rapid introduction of more efficient technologies; the major regions of the world converge economically and strongly interact. The three scenarios differ by the technological intensity of their energy sector; very intensive in fossil resources (A1FI), rapid and exclusive use of non-fossil sources (A1T) or a balanced energetic mix (A1B).

Scenario A2 - The world is very heterogeneous (the globalization movement weakens), the global population increases continuously and the economic growth and technological changes are fragmented and slow.

Scenario B1 - The regions of the world rapidly converge, the global population levels out in 2050 and the economic structure rapidly becomes a service and information economy (less intensive in material and more efficient energetically) and a global sustainable development.

Scenario B2 - Global population increases continuously, economic development and technological change are at intermediate levels, and sustainable development research is carried out at a more local level.

An analysis of the heat budget from the CIRCE simulations show that, for all of the models, the net budget is negative at the Mediterranean surface. Therefore, the basin "loses" heat from the surface, gaining heat from the Atlantic at the Strait of Gibraltar. This behaviour is in good agreement with the observations, though when considered individually the components of the simulated budget (e.g., short-wave radiation, latent heat, etc.) can differ significantly. Despite the various behaviour in the present climate, the models give a qualitatively similar response for the next decades, with an increase in solar radiation heat gain (less cloud), a decrease in the radiative heat loss (the green-house gas prevails on the SST increase), a decrease in the sensible heat loss (the air-sea temperature gradient decrease as the atmosphere warms faster that the ocean) and an increase in the latent heat loss (the atmosphere can contain more humidity in a warmer climate and Mediterranean land climate becomes drier).

The trends in temperature and precipitation found in the CIRCE projections might also affect the characteristics of the Mediterranean Sea water. Specifically, the water budget of the Mediterranean Sea and its various components (Precipitation, Evaporation, river runoff and Black Sea freshwater input) appear to be sensitive to global warming. Similarly to the heat budget, the Mediterranean Sea water budget simulated with the CIRCE models is negative, indicating that the basin "loses" water through the surface via evaporation, which is consistent with the observations. For the future period (2021-2050), the net water loss increases in all of the model projections, mostly due to a decrease in precipitation and river runoff and an increase in evaporation. More specifically, model projections suggest that the increase in sea-surface evaporation might range between +2.9% (CMIP3) (Mariotti et al. 2008) and +3% (CIRCE), whereas the reduction in rainfall can range between –7.8% (CMIP3) (Mariotti et al. 2008) and – 9% (CIRCE). Therefore, the Mediterranean Sea might lose more water through its surface along the 21st century than today. As the river discharge (runoff) also decreases, it means that this excess of water loss by the sea is not available for the Mediterranean land area but it is exported towards the rest of the planet.

These findings indicate also that the CIRCE projections are in substantial agreement with the results obtained from the CMIP3 simulations (Mariotti et al. 2008). Furthermore, the modelled tendencies appear to be consistent in sign with those observed during 1960-2000.

The CIRCE projections suggest also that the sea-surface salinity of the Mediterranean Sea might decrease due to a larger amount of Atlantic freshwater entering into the basin through the Gibraltar Strait. The uncertainty for this variable (salinity), however, is very large, with a final range

going from +0.05 to -0.35 psu., and the interpretation of the evolution of the sea-surface salinity in the CIRCE models seems to be very complex and should be made with some caution.

Changes in the Mediterranean sea level

Among other things, the CIRCE projections provide an estimate of the possible sea-level change in the Mediterranean Sea due to the steric effect, that is the change in sea level due to thermal expansion and salinity-density compensation of sea water. For the Mediterranean basin, Marcos and Tsimplis (2008) have shown that the change in sea level due to the steric effect might quite substantial.

During the reference period (1961-1990), the model ensemble mean tendency is -0.06 cm/yr, ranging from a minimum value of about -0.57 cm/yr and a maximum of about 0.17cm/yr. Combining direct observations and numerical experiments Calafat et al (2009) suggest steric effect trend values of 0.3 cm/yr for the 1993-2000 period and 0.1 cm/yr for the 1961-2000 time interval.

For future projections, Marcos and Tsimplis (2008) analyzing the CMIP3 GCMs under the A1B scenario found that the steric effect for the Mediterranean Sea might account for an average sea-level change in the range -22 and +18 cm, where the difference has been obtained from averaging over the last and the first decades of the 21st century. In the CIRCE simulations, the 2021-2050 mean steric sea level rise with respect to the reference period (1961-1990) is in the range +6.57 and +11.56 cm.

Importantly, the steric contribution is only one of the components that might influence the sea level change in the Mediterranean Sea. There are other components that might determine the sea level trends in the basin, such as the melting of the continental ice sheets (Greenland and Antarctica) that, especially on the long term (centennial time scales), might become dominant.

Changes in Extremes

Here we recall very succinctly the main findings concerning the impacts of climate change on extremes in the Mediterranean region, as obtained from different climate projections. More details can be found in Beniston et al. (2007), Goubanova and Li (2007), Ulbrich et al. (2011), Gualdi et al. (2011).

In general, climate change projections show an increase in the number of very hot days and nights as well as longer warms spells and heat waves, with the largest increases over the

Iberian Peninsula in summer. The very cold days and nights, on the other hand, exhibit a significant decrease and cold spells appear to be shorter. The projections indicate also an earlier onset and a longer duration of droughts.

Change in precipitation regimes results in an increase of heavy daily precipitation in winter over the Iberian Peninsula (except for the south), southern Italy and the Aegean area and a weak general increase in the percentage of winter precipitation in association with strong daily precipitation events. The number of the days with heavy precipitation decreases over the western and central part of the Mediterranean region, whereas they seem to increase over the northeastern part. In general, there is an increase in the intensity of heavy precipitation events over most of the Mediterranean region in all seasons.

A general decrease is found in the density of cyclone tracks. Moreover, a general decrease is found also in the frequency of cyclones associated with extreme winds, whereas no significant change is visible in the intensity of the most extreme windstorms.

Finally, concerning the extreme oceanic conditions, no substantial change is found in extreme sea level values, whereas there are suggestions of a possible general reduction of the extreme significant wave height.

In general the results obtained from the CIRCE projections and presented here are in good agreement with the results obtained from previous investigations such as the PRUDENCE Project and the studies based on the CMIP3 simulations. The consensus that we see between these different projections lead to think that these findings are robust. In particular, they appear to be robust to substantial changes in the configuration of the climate models used to produce the scenario simulations.

2.6 Changes in the climate variability

Climate change projections also appear to agree on the possible future increase in climate variability in the Mediterranean region (e.g., Giorgi and Lionello, 2008; Gualdi et al., 2011). For precipitation, the augmented variability appears to affect both the winter and summer season, though in summer the increase appears larger. In the Iberian peninsula, northwestern Africa and eastern Mediterranean areas, the increase in precipitation variability is of the order of 20%. Generally, the increased variability is more substantial for larger forcings and it appears to be

consistent with the more intense hydrologic cycle expected under warmer conditions (Giorgi and Lionello, 2008).

The change in temperature variability shows a seasonal dependence. In summer the interannual variability of the T2m increases, which is consistent with the increase in precipitation variability and the associated feedbacks between the surface water and energy budgets. The increased variability appears to be particularly intense (~1.5°C, corresponding to an increase of more than 20%) in southern Europe (Iberian Peninsula, southern France, Italy and Balkans) northwestern Africa and Middle East. In winter, on the other hand, the near-surface temperature variability shows only small changes (smaller than 10%) over most of the Mediterranean region, with some evidence of a reduced variability over the Balkans and southern Europe.

2.7 Specific characteristics of the climate change signal in the Mediterranean region

The climate change signal in the Mediterranean region appears to have many of the features observed on global scale, as shown in the final Summary section of this chapter. In particular, the Mediterranean Sea and the surrounding areas are characterized by a systematic warming trend that persisted for most of the second half of the 20th century. The Mediterranean region, however, exhibits also some distinctive behaviour that characterizes its response to the global warming. Specifically:

- **A clear signal of reduced precipitation.** Climate change projections performed with different climate models and different radiative forcing scenarios clearly show a tendency for a reduced precipitation in the Mediterranean basin, especially during the summer season. The reduced projected rainfall appears to be associated with a northward shift of the storm track and a general increase of the atmospheric stability in the basin.
- **In the Mediterranean Sea, a smaller sea-level change trend can be found with respect to the projected global sea-level rise** (Marcos and Tsimplis, 2008). This result might be due to the important role of the steric effect that characterizes the Mediterranean basin. Specifically, the strong evaporative nature of the basin and the possible increase of the evaporation found in the projections might lead to a reduced sea-level rise due to halosteric component (concerning sea-water salinity).

Summary of model climate change projections over the Mediterranean region:

- In the course of the 21st century the Mediterranean region might experience a substantial warming, which in summer might be of the order of 0.6°C/decade.
- The warming appears to be accompanied by a reduction in precipitation (projected annual mean precipitation in the 2021-2050 period decreases by about 5% compared with the mean for the 1961-1990 period) over the entire region, more pronounced in the southern and western part of the basin, during summer.
- Interannual variability of temperature and precipitation in the Mediterranean basin is projected to generally increase, especially in summer, as is the occurrence of extreme heat and drought events.
- The sea level of the Mediterranean Sea might increase causing adverse impacts on the coastal areas. The projected mean sea level rise in the period 2021-2050 due to the sole steric effect (i.e. the change due to thermal expansion and salinity-density compensation of sea water) might be in the range of about +6 / +11 cm.
- There is an expected increase in the number of very hot days and nights as well as longer heat waves. The projections indicate also an earlier onset and a longer duration of droughts.
- Overall, there is an increase in the intensity of heavy precipitation events over most of the Mediterranean region in all seasons.
- A general decrease is found in the density of cyclone tracks. Moreover, a general decrease is found also in the frequency of cyclones associated with extreme winds, whereas no significant change is visible in the intensity of the most extreme windstorms.
- These results appear to be reasonably 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.

3 EXISTING PROGRAMMES AND DATABASE FOR MONITORING CLIMATE VARIABILITY AND CHANGE IN THE MEDITERRANEAN REGION

An overview of activities for monitoring climate variability and change including the maintenance of database for climatic records currently implemented in the Greater Mediterranean Region (GMR) i.e. the region comprising the Mediterranean Sea and the surrounding areas in Europe, North Africa and Asia, is essential to avoid the duplication of efforts when designing a new programme. The review was conducted both at the regional and the national level, with a particular focus on the eligible participating countries to the UNEP/MAP full-size project *"Integration of climatic variability and change into national strategies to implement ICZM Protocol in the Mediterranean"*, namely Albania, Algeria, Bosnia and Herzegovina, Croatia, Egypt, Libya, Morocco, Montenegro, Syria, Tunisia and the Palestinian Authority.

Following this assessment, a number of gaps and needs have been identified in terms of national and regional climate variability and change monitoring activities. Proposals for developing actions that could contribute to fill in these gaps have been subsequently outlined.

3.1 Relevant transnational climate monitoring programmes

3.1.1 Global Climate Observing System (GCOS)

Coastal Mediterranean countries participate, to a different extent, in the **Global Climate Observing System (GCOS)**, an international monitoring programme under the aegis of the World Meteorological Organization (WMO), the International Council of Science (ICSU), the International Oceanographic Commission (IOC) of the United Nations Economic, Social and Cultural Organization (UNESCO) and UNEP.

The objectives of GCOS are to provide the necessary comprehensive data required for:

- climate system monitoring;
- climate change detection and attribution;
- climate change and variability response monitoring, in support of adaptation;
- application to the development of national economies;

- research on the understanding, modelling and prediction of the climate system.

GCOS does not make observations or generate data products, instead it maintains collaboration among countries carrying out both in situ and satellite systematic observations, and promotes these activities through **climate-relevant components of existing systems**, both operational and research, aimed at observing, managing data and distributing information. GCOS scope encompasses the total climate system including physical, chemical and biological properties, as well as atmospheric, oceanic, terrestrial, hydrologic, and cryospheric components.

The major components of GCOS are the following:

- **OCEAN CLIMATE OBSERVATIONS** planned jointly with the climate module of the IOC/WMO/ICSU/UNEP **Global Ocean Observing System (GOOS)** for physical, chemical and biological properties. Of particular relevance is the **Coastal module of GOOS** which is being implemented through GOOS Regional Alliances (GRA).
- **TERRESTRIAL CLIMATE OBSERVATIONS** planned jointly with the FAO/ICSU/UNEP/WMO **Global Terrestrial Observing System (GTOS)** for land surface ecosystem, hydrosphere, and cryosphere measurements, in particular through the Terrestrial Observation Panel for Climate (TOPC) and the Global Terrestrial Observing Network (GT-NET) as a master network system.
- **ATMOSPHERIC CLIMATE OBSERVATIONS** built on the **WMO Integrated Global Observing System (WIGOS)** as a concept for a comprehensive, coordinated and sustainable system of observing systems, and planned jointly with the responsible WMO Commissions and implemented within:
  - the WMO World Weather Watch (WWW) programme, a global integrated system for the collection, analysis and diffusion of meteorological data and other information on the environment. It includes, inter alia, the **Global Observing System (GOS)** for atmospheric physical and dynamical properties observed through surface stations, namely Regional Basic Synoptic Networks (RBSNs) and Regional Basic Climatological Networks (RBCNs), upper-air stations, marine stations, aircraft stations, satellite stations and other observing platforms. A selection of these surface stations form the GCOS Surface Network (GSN)[1], while a subset of these upper-air stations is part of the GCOS Upper-air Network (GUAN).[2]

[1] As of February 2011, the GCOS GSN covered 1036 stations distributed over the land areas of the globe.

[2] As of February 2011, the GCOS GUAN consisted of 170 selected upper-air stations.

- the WMO **Global Atmosphere Watch (GAW)** programme for observing atmospheric constituent and chemical properties.[3]

Other key components of GCOS are the following:

- **RESEARCH** through the **World Climate Research Programme (WCRP)** network, addressing the monitoring of terrestrial ecosystems, clouds and the hydrological cycle, the earth's radiation budget, ice sheets and precipitation over the oceans, and sea level rise; WCRP research underpins understanding of fundamental climatic changes through major core projects and other partner activities, among which the most relevant are the following:
  - Global Energy and Water Cycle Experiment (GEWEX) an integrated programme of research, observations, and science activities on dynamics and thermodynamics of the atmosphere and interactions with the Earth's surface, ultimately leading to the prediction of global and regional climate change;
  - The International Geosphere-Biosphere Project (IGBP) an international scientific research programme focused on the interactions between biological, chemical and physical processes and their impact with human systems.
- **DATA COMMUNICATION** and other infrastructures necessary to support operational climate forecasting, including the World Climate Data and Monitoring Programme (WCDMP) and the Climate Information and Prediction Services (CLIPS);

As a "system of climate-relevant observing systems", GCOS is intended to represent the climate observing component of the future **Global Earth Observation System of Systems (GEOSS).**

[3] GAW network consists of 22 Global stations, which are encouraged to participate in all the GAW measurement programmes, more than 300 Regional stations, which participate in one or more GAW programmes, and a number of associated or contributing networks that are either regionally based (e.g. EMEP), or thematically based (e.g. BSRN). Up to date information on participating stations and the measurements they make are available from GAWSIS.

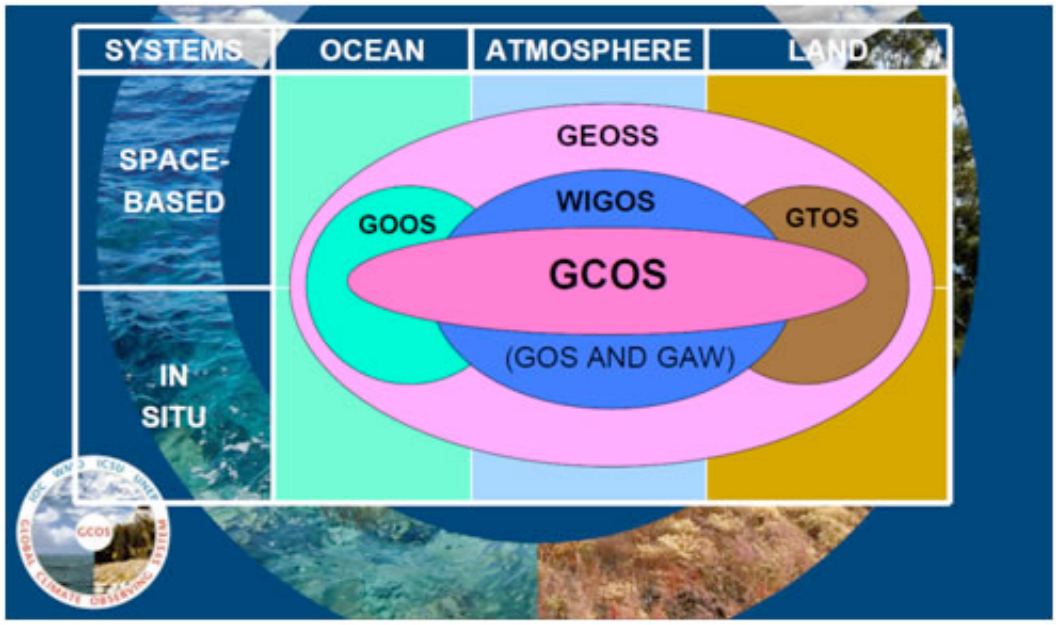

Figure 3.1: structure of the 3 Global Observing Systems (Source: WMO/GCOS)

A liaison mechanism between national entities that fund, manage and operate almost all networks, systems, data and analysis centres included in GCOS exist through the current 130 designated **National Focal Points (NFP)** for GCOS and related climatological data (from RBCN). According to the latest documentation available, as to February 2011, with regard to the Mediterranean countries it was found that each of them has an appointed NFP, with the exception of the Palestinian Authority.

NFP are responsible, inter alia, for liaising with **Lead Centres for GCOS** that have been designated by the WMO Commission for Basic Systems (CBS) for monitoring performance of GCOS networks, in particular of the GCOS Surface and Upper Air Networks (GSN, GUAN). For Northern African Mediterranean countries the responsible Lead Centre is the Direction de la Météorologie Nationale (DMN) of Morocco; European Mediterranean countries report to the Deutcher Wetterdienst (DWD) in Germany; while Syria and Turkey belong to the area covered by the Iranian Meteorological Organization (IRIMO).

GCOS Data collection and archive

A general model for the GCOS/GOOS/GTOS end-to-end data management foresees the responsibility of **National Collection Centres** for gathering specific data and metadata from national activities for one or more datasets identified by the three Global Observing Systems

(G3OS) scientific and technical panels. National Centres, that can be more than one per country or shared among countries, are responsible for processing the data as required and for forwarding it to one or more international centres for further assembly, processing, distribution, and archiving according to the needs for the variables in question. **International Operational or Research Centres** are responsible for specific activities necessary for the purposes of G3OS. The final storage of the data is carried out by long-term **Archival Centres**.[4]

The crosscutting function of disseminating information lies with the Global Observing System Information Centre (GOSIC) hosted at the US National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC). GOSIC provides an easy access to the observational requirements, data flows, and registry of datasets and products within the three Global Observing Systems as well as their partner programmes such as GAW and the GOOS Regional Alliances.

The following examples are presented in order to illustrate current Global Observing Systems data flows and archive, and are not intended to be exhaustive.

- With respect to the GCOS networks, GSN station operators are required to provide messages (SYNOP and CLIMAT[5]) to the GSN Monitoring Centre (GSNMC) at the Deutcher Wetterdienst (DWD) in Germany and to the Japan Meteorological Agency (JMA) that thus collect near real time data. These data are forwarded to NCDC acting as a GSN Analysis Center that is also responsible for collecting historical monthly and daily data and related metadata. Similarly, GUAN stations are requested to transmit observational data via GTS in the form of upper-air reports (TEMP and CLIMAT TEMP format), while metadata are made available to the final archives at a later stage by the national collecting centres. The UK Meteorological Office's Hadley Center and European Centre for Medium-term Weather Forecasting (ECMWF) are responsible for routine quality control of GUAN reports, while Hadley Center together with NCDC cooperate to act as the GUAN Analysis Center (GUAN AC). **The global archive both for GSN and GUAN data and metadata is maintained by the NCDC, located in Asheville (NC, USA).**

[4] For more information see: Model For GCOS, GOOS, and GTOS End-to-End Data Management Systems.

[5] **CLIMAT** is a code for reporting certain monthly averages/total climatological data assembled at land-based meteorological surface observation stations to data centres. Usually these messages are sent and exchanged via the Global Telecommunication System (GTS) of WMO shortly after the end of the month.

- Regarding GAW data, there are **five GAW World Data Centres** each responsible for archiving one or more GAW measurement parameters or measurement types. They are operated and maintained by their individual host institutions:
  1. World Ozone and Ultraviolet Radiation Data Centre (WOUDC) operated by the Experimental Studies Division of the Meteorological Service of Canada (MSC);
  2. World Radiation Data Centre (WRDC) located in St. Petersburg at the Main Geophysical Observatory of the Russian Federal Service for Hydrometeorology and Environmental Monitoring;
  3. World Data Centre for Greenhouse Gases (WDCGG) established at the Japan Meteorological Agency (JMA);
  4. World Data Centre for Aerosols (WDCA) operated by the European Union's Joint Research Centre, Ispra, Italy;
  5. World Data Centre for Precipitation chemistry (WDCPC) operated by Mr Van Bowersox in association with the Illinois State Water Survey and the US National Oceanic and Atmospheric Administration (NOAA).

They collect, document and archive atmospheric measurements and the associated metadata from measurement stations worldwide and make these data freely available to the scientific community. In some cases, WDCs also provide additional products including data analyses, maps of data distributions, and data summaries.

Box 3.1: GCOS CLIMATE MONITORING PRINCIPLES

Effective monitoring systems for climate should adhere to the following principles:

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.
2. A suitable period of overlap for new and old observing systems is required.
3. The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e., metadata) should be documented and treated with the same care as the data themselves.
4. The quality and homogeneity of data should be regularly assessed as a part of routine operations.
5. Consideration of the needs for environmental and climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.
6. Operation of historically uninterrupted stations and observing systems should be maintained.
7. High priority for additional observations should be focused on data-poor regions, poorly observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution.
8. Long-term requirements should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.
9. The conversion of research observing systems to long-term operations in a carefully planned manner should be promoted.
10. Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

GCOS is meant to support the work of the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC) through both current and historical observation, provision of information and international exchange of data on the selected **50 GCOS Essential Climate Variables (ECVs)** within the atmospheric, oceanic, terrestrial domain.

An update version of the ***"Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC"*** (WMO, 2010) released in August 2010 contains the latest list of GCOS ECVs, **26 identified Key Needs and 138 detailed recommended Actions** aimed at improving the availability of the observational information needed to understand, predict, and manage the countries' response to climate and climate change, in pursuing the governments' commitments under Art.4 and Art.5 of the UNFCCC. In particular, the strengthening of global observations of the GCOS ECVs, together with the support to climate research, modelling, analysis, and capacity building activities, as well as the improvement of observational records are foreseen in the 2010 Implementation Plan. When fully implemented GCOS will make available high quality climate data and derived products for climate predictions and risk assessment, which will meet both adaptation and mitigation planning needs in support of sustainable development efforts.

Box 3.2: GCOS ESSENTIAL CLIMATE VARIABLES (ECVs) - 2010 UPDATE

ATMOSPHERIC (over Land, Sea & Ice)

- SURFACE: Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation, Surface radiation budget.
- UPPER-AIR: Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget (including solar irradiance).
- COMPOSITION: Carbon dioxide, Methane, and other long-lived greenhouse gases, Ozone and Aerosol, supported by their precursors.

OCEANIC

- SURFACE: Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton.
- SUB-SURFACE: Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers.

TERRESTRIAL

- River discharge, Water use, Groundwater, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture.

GCOS in the Mediterranean Basin

The GCOS Regional Workshop Programme was initiated in 2000 upon invitation of the UNFCCC Conference of the Parties (COP) following the assessment of the adequacy of the global observing system for climate carried out in 1998 and 2003. The GCOS Regional Workshop Programme, now completed, was aimed at identifying and assessing gaps in climate monitoring programmes on a regional scale and its main goal was to propose specific actions through Regional Action Plans (RAPs). The Programme included **Regional Workshop for the Mediterranean** held in Marrakech (Morocco) on 22-24 November 2005, from whose outcomes a specific RAP for the Mediterranean Basin addressing regional priorities and ways to tackle them was developed and published in September 2006.

The **GCOS RAP for the Mediterranean Basin** is very comprehensive in identifying GCOS and regional requirements for systematic climate observations and related products in the area. Of interest for the purposes of this technical paper, it provides an assessment of the status of existing observational networks and programmes in the Mediterranean against these requirements, and proposes **16 concrete projects as well as a number of recommendations** to address gaps and deficiencies that have been recognized (GCOS/GEF/UNEP, 2006).

Building on RAP analysis, a brief and updated overview of the main existing atmospheric, marine, terrestrial and remote sensing systematic observation programmes and networks relevant for assessing climate variability and change under the umbrella of G3OS in the Mediterranean region is hereby presented.

Atmosphere monitoring

- **GCOS Surface Network (GSN);**
- **GCOS Upper Air Network (GUAN);**
- **Global Atmosphere Watch (GAW);**
- **Baseline Surface Radiation Network (BSRN)** for surface radiation budget measurements;
- **Regional Basic Climatological Network (RBCN)** comprising a selected subset of stations from the national climatological networks providing data particularly needed for regional and national scale climate impact and adaptation studies;

- **Global Network of Isotopes in Precipitation (GNIP)** of WMO and International Atomic Energy Agency (IAEA), for monitoring of the isotopic composition of monthly precipitation, useful for climatological, atmospheric and hydrological studies.

Main issues in Atmosphere monitoring in the Mediterranean Basin:

- Scarce reporting performance in a significant number of GSN and GUAN stations;
- Very poor coverage of radiosonde stations for GAW aerosol-monitoring network, especially in Northern Africa;
- Challenges in upgrading instrument calibration, observing, telecommunications, data management, quality assurance, data exchange systems and long-term support for RBCN;
- Insufficient coverage of GNIP in the Southern Mediterranean area;
- Inadequacy of databases (e.g. data stored in perishable paper documents or in obsolete electronic archives).

Ocean climate monitoring

- **Global Sea-Level Observing System (GLOSS)**, a WMO/IOC/Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) international programme aimed at establishing high quality, long-duration, global and regional sea level networks for application to climate, oceanographic and coastal sea level research.[6] GLOSS data are needed for detecting and monitoring sea level trends and to assess their impacts. Among other uses, such measurements are relevant for supporting early warning systems, coastal erosion and saltwater intrusion analysis. GLOSS requires the free exchange of sea level data stored in its archives, such as the Permanent Service for Mean Sea Level (PSMSL), the GLOSS Station Handbook and the GLOSS Fast Data Center at the University of Hawai`i Sea Level Center;
- **Monitoring Network System for Systematic Sea Level Measurements in the Mediterranean and Black Sea (MedGLOSS)** is a GLOSS regional subsystem established by the IOC and the Commission Internationale pour l'Exploration Scientifique de la Mer

[6] The main component of GLOSS is the Global Core Network (GCN) of 290 sea level stations around the world for long-term climate change and oceanographic sea level monitoring. Other components are the Long Term Trends (LTT) set, comprising gauge sites for GPS installations to monitor vertical land movements; the Altimeter Calibration (ALT) set, consisting mostly of island stations; and the Ocean Circulation (OC) set, used to complement altimetric coverage of the deep ocean and including gauge pairs at straits and in polar areas.

Mediterranée (CIESM) for increasing density to the network of sea level monitoring in the Mediterranean and Black Sea. Its main objectives include detecting regional long-term relative and absolute sea level changes trends and acceleration rate as well as determining plate tectonic movements. The Pilot MedGLOSS network[7] is intended to work in cooperation with the European Sea Level Service (ESEAS). These bodies coordinate the collection and dissemination of sea level data, of particular relevance to GCOS and climate change assessment studies. They aim at facilitating the performance of regional studies by providing standardized quality controlled data. MedGLOSS also provides assistance, education and training to its members.

- **Mediterranean Operational Oceanography Network (MOON)** is a network gathering marine research centres within the Mediterranean Basin with the aim of designing and implementing the regional operational ocean observing system and the Mediterranean Forecasting System (MFS), promoting the development and optimization of the scientific base, the technology and the information system for operational oceanography. So far MFS has been implemented through several European projects and national initiatives.[8]By providing high quality observational data on surface and subsurface ECVs, as well as related model output analyses and derived products, MOON contributes directly to the GOOS needs for oceanographic data and products, and to the goal of consolidating and expanding the concerted monitoring and forecasting systems for sustainable development, marine state assessment and risks management. MOON is chaired by the Istituto Nazionale di Geofisica e Vulcanologia - (INGV) (Italy) and Mercator (France). The MOON Information Management System has been defined and maintained in the past years and it consists of a Web Portal with a simple cataloguing, discovery and downloading service.
- **Mediterranean Global Ocean Observing System (MedGOOS)** is the GOOS Regional Alliance in the Mediterranean with a membership of 19 members from 16 riparian

[7] MedGLOSS currently consists of 43 stations, split into near real time stations (15) and delayed mode stations. Minimum data include hourly averaged values of sea level and atmospheric pressure.

[8] The existing system data collection capability at basin scale includes: The real time satellite observations; The Ship Of Opportunity Program (SOOP) providing profiles of temperature, now being evolved into a Voluntary Observing Ship (VOS) for the surface meteorological measurements; The ARGO program in the Mediterranean (MedArgo); The Mediterranean Moored Multi-sensor Array (M3A) i.e. the network of moored Eulerian observatories, now coordinated under OceanSITES project; The Glider operations under the European Gliding Observatories (EGO) initiative.

countries including non-EU countries. It is established under the auspices of UNESCO-IOC to provide a regional framework for promoting regional development of operational systems through partnerships, synergies, sharing of expertise, technology and capacity building for operational oceanography. The MedGOOS Secretariat is established in Malta at the IOI-Malta Operational Centre (University of Malta); the current Chair is from the Hellenic Centre for Marine Research.

Main issues in Ocean Climate monitoring in the Mediterranean Basin:

- Maintenance of quality and reliability of sea level monitoring and reporting at GLOSS sites;
- Regional requirements for expansion of sea level observations, particularly in Northern Africa;
- Urgent implementation of the major components of MOON observing systems;
- Priority on rescue and preservation of historical oceanographic data records.

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Terrestrial climate monitoring

For the purpose of this study the priority is given to climate-relevant programmes for monitoring of water resources and terrestrial ecosystems.

- **Global Terrestrial Network on Hydrology (GTN-H)** under the umbrella of GT-Net, it is a evolving network that includes existing networks, global databases and global data product centres, aimed at developing and improving the availability of hydrological data and information required to address global and regional climate, water resources and environmental issues by providing the observational data records and products. GTN-H has created an inventory of hydrological data and product sources. GTN-H and other associated Global Networks[9] rely on national hydrological networks, regional programmes and three major networks and global database: Global Runoff Data Centre (GRDC), Global Precipitation Climatology Centre (GPCC), Global Environment Monitoring Centre on Water Quality (GEMS).
- **Mediterranean Hydrological Cycle Observing System (MED-HYCOS)** as the first regional component of the WMO World Hydrological Cycle Observing System (WHYCOS) contributes to water resources assessment and management by helping the National

[9] More Global Terrestrial Networks have been established for: River Discharge (GTN-R), Glaciers (GTN-G), Permafrost (GTN-P) and a future network on Lakes (GTN-L).

Hydrological Services to strengthen their capacities and by promoting the exchange of information and skills. MED-HYCOS included the implementation of a real-time Data Collecting Platform (DCP) network on major rivers of the Mediterranean, the development of a Hydrological Information System, and training activities.[10]

- **Flow Regimes from International Experimental and Network Data (FRIEND)** as an international research programme on regional hydrology and its related project focused on the Mediterranean MED-FRIEND, including a comprehensive database encompassing 17 countries.
- **Long-term Ecological Monitoring Observatories Network (ROSELT)** focusing on the Sahel and Saharan region, is a programme managed by the Sahara and Sahel Observatory (OSS) aimed at improving the understanding of desertification processes and the regional ecosystems. The network today comprises 25 observatories or clusters of observatories spread around Sahara and located in 11 countries.

Main issues in Terrestrial Climate monitoring in the Mediterranean Basin:

- Need for additional observational hydrological information (e.g. on groundwater) and better quality;
- Need for expansion of hydrological and ecosystem monitoring, particularly in the Southern and Eastern part of the Basin;
- Need for modernization of instrumentations;
- Capacity-building needs, including exchange of expertise and research results.

Remote sensing monitoring

- **European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)**'s Satellite Application Facilities (SAFs) are dedicated centres of excellence for processing satellite data and are part of the distributed EUMETSAT Application Ground Segment. The existing 8 SAFs generate and disseminate operational EUMETSAT products and

[10] About 50 Data Collecting Platforms (DCPs) installed in Albania, Bosnia, Bulgaria, Cyprus, Croatia, Malta, Slovenia, Morocco, Tunisia, Turkey, Jordan, Lebanon, Macedonia, and Palestinian Territories. Furthermore, this network has been completed by a secondary network of Near Real Time Stations (NRT), established in Albania, Bulgaria, Spain, France, Italy, Greece, Slovenia and Romania.

services.[11]Each SAF is led by the National Meteorological Service of a EUMETSAT Member State in association with a consortium of EUMETSAT Member States and Cooperating States, government bodies and research institutes. Of relevance for this study, inter alia, **SAF on Climate Monitoring (CM SAF)** is led by the Deutscher Wetterdienst (DWD) (Germany) and generates and archives high-quality datasets of parameters of the energy and water budget. The applications meet the goals of various international programmes (such as GCOS and WCRP) and are also vital for activities within the GEO and GMES framework.

- **GIE/EIG EUMETNET** : the Network of European Meteorological Services gathers 26 European National Meteorological Services that provides a framework to organise co-operative programmes between the Members in the various fields of basic meteorological activities such as observing systems, data processing, basic forecasting products, research and development, training.

Main issues in Remote Sensing monitoring in the Mediterranean Basin:

- Restricted access to satellite and data products for North African countries in relation to second generation of meteorological satellites METEOSAT (MSG) and Metop;
- Need for remote sensing infrastructure investments and capacity building.

Regional Coordination and Organization

By its nature, GCOS is implemented in a non-coordinated manner being national contributions often delivered by diverse agents. Some structures do exist at the regional scale (e.g. MedGOOS) and sub-regional scale (e.g. OSS), however a single forum specific for systematic observation of the overall climate system is lacking in the Greater Mediterranean Region.

Main issues in Regional Coordination and Organization in the Mediterranean Basin:

- Need for a GCOS coordination mechanism for systematic observation activities on the climate system in the Mediterranean.

[11] 1) SAF on Support to Nowcasting and Very Short Range Forecasting; 2) SAF on Ocean and Sea Ice; 3) SAF on Climate Monitoring; 4) SAF on Numerical Weather Prediction; 5) SAF on Land Surface Analysis; 6) SAF on Ozone & Atmospheric Chemistry Monitoring; 7) SAF on GRAS Meteorology; 8) SAF on Support to Operational Hydrology and Water Management.

In the light of the assessment carried out in the RAP, 16 projects were proposed and approved for the Mediterranean Basin (see Table 3.1) for addressing the identified key gaps and needs. They follow three broad themes:

1. the strengthening of basic structures (such as observational stations and networks and coordination mechanisms);
2. the enhancement of capacities for data analysis and prediction (e.g. Regional Climate Models)
3. applications to user requirements (e.g. early warnings for droughts and locusts).

At present, the proposed projects are at different stages of implementation. No detailed updated information was available at the time of writing.

With respect to the gaps assessed in oceanographic observations in the Mediterranean, particularly relevant for climate change and variability issues in coastal zones, the collective efforts of the MedGOOS and MOON communities over the past years were devoted to the improvement and consolidation of the basin scale monitoring and forecasting systems that were developed by several EU funded projects. The effort is ongoing and the community is currently participating in projects addressing the in-situ observing infrastructures (EuroARGO - European contribution to ARGO programme; EuroSITES - European Ocean Observatory Network) or research oriented projects that improve modeling capabilities and understanding of Mediterranean marine dynamics (CIRCE; SESAME - Southern European Seas: Assessing and Modelling Ecosystem changes; ECOOP - European COastal sea Operational observing and Forecasting system). These initiatives continue to create a capacity to monitor and forecast the physical state of the Mediterranean Sea with appropriate resolution for basin scale and shelf seas applications, while first steps towards an analogous capacity for the ecological state are underway.

Action field	Project No. / Title	Gap/Need addressed	Expected Output	Potential Partners
Coordination and Capacity Building	**Project No.1 "Establishing a Cooperative Mechanism for GCOS in the Mediterranean Region (MedGCOS)"**	Strengthening coordination of GCOS activities in the Mediterranean Basin	GCOS-related coordination among the nations of the Mediterranean Basin, with the European community, and with other international agencies and institutions will be improved. This will facilitate the implementation	Open to Mediterranean countries

			systematic observation programmes.	
	Project No.2 "PRECIS and Capacity Building (PACAB)"	Need for the most accurate information possible on future climatic conditions and their likely national and regional impacts to be used by Governments and decision-makers.	Mediterranean Basin countries will be enabled to apply regional modeling and downscaling techniques to develop future climate scenarios needed to support adaptation to the impacts of climate, pursue sustainable development, and respond to requirements of the UNFCCC and Kyoto Protocol.	---
	Project No.3 "Meteorological Assistance to Building the Capacity of Teachers in the Field of Climate Change (ADIM)"	Commitments under Article 6 of the United Nations Framework Convention on Climate Change (UNFCCC).	Students and future citizens in Mediterranean countries will develop awareness and understanding of climate and climate change, the processes that control them, their impacts on society, and the economy and the measures that can be taken to mitigate or adapt to these impacts.	NMHSs of North African countries and the Mediterranean Basin Educational bodies of these countries
Atmospheric Networks and Observations	**Project No.4 "Improving the GCOS Surface and Upper-Air Observing Networks in North Africa"**	Critical deficiencies in GNS and GUAN observing stations especially in Northern Africa, where stations are inadequately resourced over the long term.	Observations from GSN and GUAN stations in the Mediterranean Basin will meet the demanding GCOS quality and timeliness standards. These data will contribute to validating outputs of climate models, calibrating satellite remote sensing measurements, and planning and operations related to water resources management, irrigation, locust control, agriculture, and other sectors.	Algeria, Egypt, Libya, Mauritania, Morocco, Tunisia
	Project No.5 "Improving GAW in the Mediterranean Region: Emphasis on Aerosols"	Major gaps in the GAW aerosol-monitoring network coverage in North Africa and the Central Mediterranean Sea.	An upgraded GAW research and observation programme will deliver high quality aerosol and other data and research products to meet national, regional, and global requirements for such data in managing air pollution and addressing climate variability and climate change.	---
	Project No. 6 "Building Observational and Monitoring Capacity related to the Isotopic Composition of Rain Water in the North African Region (ISOTOPE)"	Poor development of GNIP network in the southern sections of the Mediterranean Basin.	North African countries will acquire enhanced capacity to utilize isotopic methods to detect and monitor climatic and hydrologic variations and trends along with an improved monitoring network for isotopes in precipitation	---
Oceanographic Observations and Networks	**Project No.7 "Mediterranean Sea Level Monitoring for Climate Change and Alerting on Tsunamis and Other Sea Level**	GCOS priority on monitoring sea level around the globe.	Systematic measurements of sea level from all Mediterranean Sea coasts, including North Africa, will be available to climate scientists and decision makers	Algeria, Croatia, Cyprus, Egypt, Germany, Greece, Israel, Italy, Malta, Russia, Spain, Morocco, Tunisia

	Hazards (MEDALERT)"		enabling them to assess climatic and sea level trends, plan coastal zone developments, and undertake harbour operations and other applications.	
	Project No.8 "Consolidation of the Mediterranean Operational Oceanography Network (MOON) Core Services in Support of Climate Change Monitoring and Assessment (MOON4CLIMATE)"	Need to strengthen and sustain oceanographic climate monitoring in the Mediterranean.	Representative oceanographic and atmospheric observations in and over the Mediterranean Sea will be available to support climate assessment and prediction as well as underpin the provision of operational ocean services.	Croatia, Czech Republic, Cyprus, Egypt, France, Greece, Israel, Italy, Malta, Slovenia, Spain, Tunisia, Turkey
	Project No.9 "Climatological Monitoring of the Mediterranean Sea, Assessing and Modelling the Ecosystem Changes and the Climate Change Impacts - MEDSEA-CLIM"	Priority on the areas of deep and intermediate water formation for monitoring changes of the deep circulation of the basin. Need for extended time series. Need for consolidating recent operational oceanography's multiplatform observing system.	Systematic oceanographic observations will be available from climatically sensitive deep waters and straits in the Mediterranean Sea to permit the identification and assessment of climatic trends and variations.	---
Terrestrial Networks and Observations	**Project No.10 "Improving Hydrological Observations for Climate in the Southern Mediterranean and the Nile Basin"**	Inadequacy and deteriorating conditions of hydrological networks and systems for data collection in the southern Mediterranean and the Nile basin.	High quality, long-duration, hydrological observations will be available from an improved, more representative, observation network to support climate assessments and water resources planning and management.	---
	Project No.11 "Long-Term Environmental Monitoring to Reduce the Impact of Climate Change on Natural Resources and Human Wellbeing in the Circum-Sahara Zone"	Available environmental data and products are of uneven quality and display several shortcomings within the countries of the Sahara and Sahel.	High quality terrestrial and associated atmospheric climate observations will be available from the vulnerable Sahara/Sahel region, enabling the detection and assessment of the impacts of climatic variations and trends on vegetation, desertification, drought, and human and animal health.	Algeria, Egypt, Ethiopia, Cape-Verde, Kenya, Libya, Mauritania, Mali, Morocco, Niger, Senegal and Tunisia
Data Rescue and Data Quality	**Project No.12 "The Development of Mediterranean Historical Climate Data and Metadata Bases - A GCOS DARE Project (MedMEDARE)"**	Under-exploitation of the rich climate data heritage in the atmospheric and surface domains of the Mediterranean Basin.	Vulnerable historical records of Mediterranean climate observations will be rescued, preserved, and made accessible to decision makers and other users, enabling the identification of historical variations and trends in climate.	Algeria, Cyprus, France, Italy, Morocco, Spain, Tunisia, Turkey, International Environmental Data Rescue Organization (IEDRO)
	Project No.13 "An Assessment of the Use of Regional Instrument Centers for GCOS Global and Regional Stations in the	Need of regular use of the WMO Regional Instrument Centres (RIC) for calibration and maintenance of meteorological	Atmospheric observations will meet the accuracy standards required for the detection and assessment of climate variability and climate change, ensuring that	WMO members in the Mediterranean

	Mediterranean Basin"	instruments in the Mediterranean Basin by WMO Members.	measurements of climate variables are compatible across all countries.	
Applications of Climate Information	**Project No.14 "Establishment of a Watch and Early Warning System Against Locust Invasions"**	Importance of information on climatic conditions in the management and organization of the preventive control system for migratory locusts, particularly in the Sahel and Maghreb.	The battle against locust infestations will be supported by timely and appropriate climate information and warnings. This will help agencies whose mission is to combat locusts to anticipate explosions of locust populations and predict or anticipate their migration patterns.	Algeria, Morocco, Mali, Niger, Chad, Mauritania, FAO
	Project No.15 "Establishment of an Early Warning System for Drought in the Mediterranean"	Need to address drought events as regional, border-crossing phenomena in the Mediterranean Basin.	Decision makers in Mediterranean countries will have access to state-of- the-art drought monitoring information and predictions. This will enable them to plan optimal actions to mitigate the adverse impacts of drought.	Algeria, Morocco, Tunisia, Egypt, Libya, Mauritania
	Project No.16 "Control of Water and Plant Protection Products in Irrigated Plots in semi-Arid Zones"	Priority of the Mediterranean Commission for Sustainable Development on the improvement of water resources management for agricultural and rural development.	Farmers will be better able to conserve water and minimize the use of agricultural chemicals through access to timely and relevant climate information and products (e.g., precipitation, evapotranspiration, insect/fungal risk, etc.).	Tunisia, Algeria, Morocco, other Mediterranean countries

Table 3.1: Projects presented in the GCOS Regional Action Plan for the Mediterranean Basin (Source: GCOS/GEF/UNEP, 2006).

3.1.2 Global Monitoring for Environment and Security (GMES)

Global Monitoring for Environment and Security (GMES) is the European Earth observation programme that has been developed over the last 10 years through numerous European R&D projects. GMES is made of a complex set of systems dedicated to a systematic monitoring and forecasting, which provides collection of data from multiple sources (earth observation satellites and in situ sensors such as ground stations, airborne and sea-borne sensors), data processing and dissemination of reliable and up-to-date information to users.

GMES focuses on six thematic areas: marine, land, atmosphere, emergency, security and climate change. **A land monitoring service (provided by the EU-funded project geoland2 - Operational Monitoring Services for our Changing Environment), a marine monitoring service (provided by the EU project MyOcean - Ocean Monitoring and Forecasting) and an atmosphere monitoring service (provided by the EU project MACC - Monitoring Atmospheric Composition**

and Climate) contribute directly to the monitoring of climate change and to the assessment of mitigation and adaptation policies. Two additional GMES services address respectively emergency response and security-related aspects. Some of these systems and data sources are already fully operational, and prototype services are available but many developments are still required in all domains.

With particular regard to the marine monitoring services, the main operational capacity is expected to be enhanced in the next years under the **GMES Marine Core Service (MCS)** that will be coordinated by the MyOcean project between 2009 and 2012. Meantime the infrastructural capacity is being enhanced through the EuroARGO project developing a European Infrastructure for the maintenance of the ARGO observations that are particularly important in the Mediterranean Sea. Another significant development is the proposed network of excellence, the European Seas Observatory Network (ESONET) representing a sub-sea component of GMES, along with the European Multidisciplinary Seafloor Observatory (EMSO), which shall provide long-term monitoring capabilities, mainly in real-time, of environmental processes related to the interaction between the geosphere, biosphere, and hydrosphere, including natural hazards.

3.2 Relevant national climate monitoring activities

All countries, with the exception of the Palestinian Authority, participate to the WMO Programmes including the component of Global Observing System (GOS) and its regional programmes and are Parties to the UNFCCC. Information on climate variability and change monitoring activities were obtained through available country reports to UNEP/MAP prepared by national consultants as well as the submitted National Communications to the UNFCCC.

Albania

Albania is member of WMO. According to the UNEP/MAP country report (Diku, 2011) the systematic monitoring of climate change and variability in Albania is performed by the Institute of Energy, Water and Environment (IEWE), part of the Polytechnic University of Tirana, which inherited all the capacities and network of the former Hydro-Meteorological Institute. The main components of the national monitoring network are: a meteorological and a hydrological network.

IEWE is also the key research institution performing basic and applied scientific studies on climate change, along with the Faculty of Natural Sciences of the University in Tirana and other academic institutions (Islami B, Kamberi M, Demiraj Bruci E, Fida E, 2009).

Currently there is no acknowledged national monitoring programme on climate variability and change. However, the country runs an environmental monitoring programme supported by the Ministry of Environment and the existing network of research institutions, which can be functional also to climate change assessment.

ALBANIA				
	Description	**Responsible authority**	**Scope**	**Identified gaps**
Systematic observation	National monitoring network	IEWE	126 meteorological stations 103 hydrological stations, from which 92 in rivers, springs and channels, 6 stations in seacoast and lagoons and 5 in lakes	Reduced number and capacity of stations over time
Relevant database	Database of the national monitoring network	Data collection and processing centre in Tirana	Air temperature (all indexes - minimum, maximum, and mean); precipitation (daily, monthly, yearly amount, intensity for different time duration etc.); wind; sunshine radiation; humidity, etc. Mean daily water level, monthly and yearly mean, maximal and minimal water level, daily discharge and monthly and yearly mean, maximal and minimal discharge	Procedure of data transmission from stations not adequate Stuck process for data collection and processing due to lack of digital network No digital database, only hard copy Lack of funding for staff training
Relevant national monitoring programmes	Environmental monitoring programme	Ministry of Environment Existing network of research institutions	Environmental parameters Data on water resources (quality and quantity), climate, air quality, vegetation, fauna census, etc	No clear focus on climate change parameters No monitoring of climate change effects on coastal areas

Algeria

Algeria is member of WMO and the responsibility for systematic observation in the country lies with the National Meteorological Office (Office National de la Météorologie - ONM). Recently, the national monitoring network has been enhanced with, inter alia, the creation of a Regional Climatological Centre (Centre Climatologique Régional - CCR) linked to ONM, which shall ensure the collection and diffusion of climatological information and products. It is worth mentioning that Algeria has approved an ambitious national space programme that may improve national systematic observation over the next 15 years (2020).

The country hosts the only GAW Global Observatory of the Mediterranean Basin, located at Tamanrasset, in addition to a number of GAW Regional and contributing stations located in the Greater Mediterranean Region.

With respect to monitoring of climate change and variability, there are no specific programmes in place within the country. However, according to the Report to UNEP/MAP from national consultant (Unknown author, 2011), a number of different actions have been undertaken by the Algerian Ministry for the Territory and the Environment (Ministère de l'Aménagement du Territoire et de l'Environnement - MATE) together with UNEP and MED POL Programme, the marine pollution assessment and control component of MAP, as well as the National Observatory of Environment and Sustainable Development (Observatoire National de l'Environnement et du Développement Durable - ONEDD), which can be of relevance. In particular, atmospheric pollution and desertification are the objects of specific systematic monitoring programmes carried out by a number of institutions and structures at different scales.

Furthermore, a Geographic Information System (GIS) on marine and coastal biodiversity implemented and finalized in 2006 by MATE, allowed the creation of a database containing useful information for the management of the Algerian littoral.

ALGERIA				
	Description	**Responsible authority**	**Scope**	**Identified gaps**
Systematic observation	National monitoring network	ONM	76 synoptic stations, 22 automatic climatological stations for real time transmission, 178 automatic climatological stations for monthly transmission, 200 conventional climatological sites, 3 research and special observation sites	---
Relevant database	GIS Database on marine and coastal biodiversity	MATE	14 coastal Provinces	---
Relevant national monitoring programmes	Environmental monitoring programmes	MATE UNEP MED-POL ONEDD Several institutions at different scales	Terrestrial and Marine variables, Atmospheric and marine pollution data, Biodiversity	Not specifically focused on climate change
	National space programme		Potentially all segments of climate system	---

Bosnia and Herzegovina

Bosnia and Herzegovina is member of WMO represented by its Federal Meteorological Institute. According to the Initial National Communication to the UNFCCC, the modernization and expansion of the hydrometeorological network is strongly needed to recover the capability lost with the strong shrinkage due to the war in 1992.

Currently, information on specific national programmes on monitoring climate change and vulnerability and related database are not available. On the other hand, it is acknowledged that the country has succeeded in developing the concept of sustainable development on environmental principles through a number of regional international programmes initiated since 1997 (Ministry of Physical Planning, Civil Engineering and Ecology, 2009).[12]

BOSNIA AND HERZEGOVINA				
	Description	**Responsible authority**	**Scope**	**Identified gaps**
Systematic observation	National monitoring network	Federal Meteorological Institute	Bosnia and Herzegovina: 13 professional weather stations Republic of Serbia: 26 meteorological stations	Hydrometeorological network experienced drastic shrinkage after 1992 Need to further expand and modernize the network by the introduction of Automatic Weather Stations and their connection into a system of automatic monitoring together with hydrological stations
Relevant Database	---	---	---	---
Relevant national monitoring programmes	---	---	---	---

Croatia

Croatia is member of WMO, represented by the national Meteorological and Hydrological Service, and participates to WMO programmes on climate variability and change and its technical commissions.

Due to the availability of long-term climatological time series, starting in 1861, a good basis for climate monitoring is acknowledged in the country. Data archives are maintained by the

[12] The most relevant are: the World Bank project for developing a National Environment Action Plan (NEAP) for Bosnia and Herzegovina; the Regional Environment Reconstruction Programme for South Eastern Europe (REReP, a Stability Pact programme); the Mediterranean and Danube basin plans under the auspices of the MAP; and the International Commission of Protection of the Danube River (ICPDR) and the Danube-Black Sea (DABLAS) programmes under the auspices of the Danube Convention and the Black Sea Convention.

Meteorological and Hydrological Service of Croatia and are partly available in electronic ASCI format.

However, according to the Fifth National Communication to the UNFCCC (Ministry of Environmental Protection, Physical Planning and Construction, 2010), Croatia shows a number of gaps and barriers in its national existing observing systems that are to be overcome. In particular, the existing system for the collection of data relating to the sea level changes, sea current directions and forecasts of wind waves along the eastern Adriatic coast is to be improved.

Available information indicates that Croatia does not show existing national monitoring programmes specifically focused on climate variability and change at the present time.

CROATIA				
	Description	**Responsible authority**	**Scope**	**Identified gaps**
Systematic observation	National monitoring network	Meteorological and Hydrological Service	41 main (M), 117 climatological (C), 336 precipitation (P) and 23 rain storage stations Automated weather stations (AMS) co-located at 32 main meteorological station sites, and 26 AMS installed at other locations more than 100 hydrological, 30 phenological and 5 marine stations for sea-level including about 30 sea surface temperature gauges in Croatian coastal area	---
Relevant database	Database of the national monitoring network	Meteorological and Hydrological Service	---	Shortage of adequate amounts and quality of data on thematic areas (e.g. SLR, water, biodiversity and natural terrestrial ecosystems, forestry) Electronic format not available before 1980
Relevant national monitoring programmes	---	---	---	---

Egypt

The Egyptian Meteorological Authority represents Egypt within WMO. According to the available documentation provided to UNEP/MAP from national consultants, the current systematic monitoring network and data basis available for climate change and/or ICZM is rather limited.

The only relevant monitoring systems with quality controlled and quality assured data are acknowledged to be the Egyptian Environmental Affairs Agency (EEAA) Environmental Impact

Monitoring Programmes (EIMP) for Air pollutants (CO2, and particulates levels), and Coastal and marine pollution monitoring along the Mediterranean and the Red Sea coastal zone. Data collection is managed by the Institute of Graduate studies and Research (IGSR) of university of Alexandria for the Mediterranean coast and the National Institute of Oceanography and fisheries (NIOF) for the Red Sea coasts.

The Second National Communication to the UNFCCC (Egyptian Environmental Affairs Agency, 2010) foresees the need for establishing a specific programme/project for monitoring and observing climate change, as well as a possible Regional Center for Research and Studies of Climate Change that would be responsible for data collection, monitoring and assessment of climate change and likely impacts within Nile Basin, development and maintenance of a database.

EGYPT				
	Description	**Responsible authority**	**Scope**	**Identified gaps**
Systematic observation	National monitoring network	Egyptian Meteorological Authority	---	Limited institutional capability for data verification, dissemination and analysis
Relevant database	National monitoring network	--	Data from the Egyptian Meteorological organization; Satellite images from NARSS; Tide gauges data as collected by the ports and by the Coastal research institute; Collected data by the Ministry of State of Environmental Affairs; Collected systematic observations carried out by EEAA/EIMP programmes; Data collected by projects on Natural Protectorates concerning wetlands, water quality.	---
		Coastal Research Institute (CoRI) of the Ministry of Water Resources	Tide gauges data	---
		National Institute of Oceanography and Fisheries (NIOF)	Oceanographic data	---
Relevant national monitoring programmes	EIMP programme	EEAA	Coastal pollution monitoring and Air pollution programme	Not specifically on climate change and variability

Libya

Libya takes part to WMO and its programmes through the Libyan National Meteorological Centre. Meteorological services started before 1950 in the country, not exceeding the issuance of some weather reports and forecasts for air navigation. In 1991 the meteorological sector was defined according to scientific developments as well as local and international requirements.

At present, no other information on climate monitoring and related programmes was found to be available.

Morocco

The Moroccan Direction Nationale de la Météorologie (DNM) represents the national services within WMO. DMN is the designated GCOS Lead Centre for North African countries. Several institutions are involved in the country's monitoring network, besides DNM, such as the Centre Royal de Télédétection Spatiale (CRTS), the Direction Générale de l'Hydraulique (DGH), related Basin Agencies and other institutes and research centres, which ensure the basic climate and climate change observations. The system includes: a meteorological network, an air-quality control network, a hydrological network, a monitoring network for water quality, a flood early-warning network, a drought monitoring network, remote sensing oceanographic observations. Morocco has a climatological database managed and maintained by the MND. However, the series are relatively short and rarely cover the periods before 1960. The Basin Agencies also provide a hydrological database (BADRE 21) archiving series of flows and piezometric levels of groundwater. Tide gauge data, however, are embryonic and dispersed.

In general, the existing monitoring programmes have been developed independently and for sectoral purposes which could be long-term and systematic as in the case of climatology, or limited in time and punctual as in the case of tides measurements for characterization of port sites (Jalil, 2011). Anyway, none of these programmes was specifically designed to monitor climate change, a relatively recent issue with varying degrees of urgency reflected in these existing programmes.

Nevertheless it is worth recalling that in response to national concerns, including those relating to drought and the prevention of extreme events (floods, flash floods), DMN has been working on research programmes including climate monitoring, scientific and technological watch programmes, drought management studies, programmes on the development of nowcasting and

assistance to sectors that use weather information (Ministère de l'Aménagement du Territoire, du l'Urbanisme, de l'Habitat et de l'Environnement, 2010).

MOROCCO				
	Description	**Responsible authority**	**Scope**	**Identified gaps**
Systematic observation	National monitoring network	DMN CRTS DGH and related Agences des Bassins Hydrauliques Direction des Ports et du Domaine Public Maritime	44 Synoptic stations 19 stations for air quality control 265 Hydrological stations ….	Time series don't allow to detect climate change trends on SLR Tide gauge data embryonic and dispersed
Relevant database	Database of national monitoring network	DMN	Main meteorological variables Climatological data	Short time series (rarely available data before 1960)
	Hydrological database (BADRE21)	DGH	Hydrological data	---
	Database for remote sensing observations	CRTS	Map and statistical database on land use and forest dynamics	---
Relevant national monitoring programmes	Drought monitoring	Observatoire National de la Sécheresse (ONS)	---	Not specifically focused on climate change
	Research programmes	DMN	Characterization of past climates, monitoring of weather conditions course, seasonal predictions (new indices and new techniques), and simulation of changes in the region over the next fifty years.	---

Montenegro

Montenegro is member of WMO and participates to its programmes and regional projects. The Hydrometeorological Institute of Montenegro is the responsible authority in the country for climate monitoring and research. Its activities are conducted independently or in cooperation with relevant ministries, the environmental Protection Agency (ePA), weather bureaus in the region and the appropriate educational and scientific institutions. Data and information necessary for climate change risk assessment and development of adaptation strategies are provided by the Hydrometeorological Institute.

Activities of the Institute include a programme to improve the meteorological, hydrological and hydrographic information system, as well as climate research and the assessment of possible

impacts of climate change on society. Furthermore, efforts are made to intensify the application of satellite observations in the context of EUMETSAT membership, improve analytical and forecasting systems as well as early warning systems for atmospheric and hydrological disasters and climate extremes, maintain databases on climate including information about the projections of regional and local climate change for the territory of Montenegro (Ministry for Spatial Planning and Environment, 2010).

Specific monitoring programmes for climate variability and change are not acknowledged to be in place within the country, however a number of measures like water quality monitoring (including eutrophication, biomonitoring), air quality monitoring, soil quality monitoring and in particular biodiversity monitoring programmes contribute to the overall observation of climate variables.

MONTENEGRO				
	Description	**Responsible authority**	**Scope**	**Identified gaps**
Systematic observation	National monitoring network	Hydrometeorological Institute of Montenegro	Meteorological stations Hydrological stations Hydrographic stations	---
Relevant database	Database of national monitoring network	Hydrometeorological Institute of Montenegro	Meteorological, hydrological and hydrographic data	Weak
Relevant national monitoring programmes	Biodiversity monitoring programme		Representative species and habitats of international and national importance; biodiversity of Lake Skadar	Not specifically focused on climate change

Syria

Syria is member of WMO and the main responsibility for collecting meteorological data lies with the General Directorate of Meteorology and its departments, affiliated with the Ministry of Defence. Other governmental authorities are involved in the monitoring programme such as the Ministry of Agriculture and Agrarian Reform and the Ministry of Irrigation. Such an institutional setting does not seem to allow the most favourable conditions for coordinated systematic data collection, analysis and dissemination.

A common database between the different relevant agencies on climate patterns was recognized to be missing. For instance, climate data in the coastal region are dispersed within different institutions.

The country has not implemented a specific climate change monitoring programme, and neither a an early warning system or national preparedness plan aimed at drought surveillance

which is acknowledged to be one of the major issues in Syria (Kayyal, 2011). Furthermore, there are not designated focal points or institutions that could act as a central coordination unit for data collection, analysis and dissemination on drought monitoring.

SYRIA				
	Current status	**Operating authority**	**Scope**	**Identified gaps**
Systematic Observation	National monitoring network	General Directorate of Meteorology Other governmental institutions	Over 30 synoptic stations in the coastal area	No formal intergovernmental procedures for systematic data collection, Lack of integration between institutions Poor infrastructure, slow modernization Remote sensing sector does not have the necessary capabilities for modeling and prediction
Relevant database	Database of the national monitoring network	General Directorate of Meteorology	Mainly atmospheric data	Possible inaccuracy of monitoring data due to bad conditions of stations and lack of continuity in time and space Poor quality of the available data sometimes not allowing for further analysis Lack of data on precipitation, sea level and tides
Relevant national monitoring programmes	---	---	---	---

Tunisia

Tunisia's National Institute of Meteorology (NIM) represents the country within WMO. Among other activities, it covers the operations related to observation, storage, exchange and processing of meteorological data, climatology and applied meteorology. A climatological database is in place within NIM, where all data from 1950 onward is available on magnetic support. Such climate database is managed by an information system that comprises software and analysis tools so as to enable internal and external users to use NIM climate data.

In matter of climate change monitoring, no specific programmes seem to be in place at present. According to the National Report on the State of the Environment, the year 2008 reported the completion of research programmes, which could be of some relevance, including the "Preparation of an action plan for adaptation of the coastline to climate change". This study put forward an action plan aimed at the prevention of the likely impacts of a potential rise in sea level which comprised a set of programmes and projects including the stepping up the

environmental monitoring of coastal ecosystems (Ministry of Environment and Sustainable Development, 2008).

TUNISIA				
	Description	**Responsible authority**	**Scope**	**Identified gaps**
Systematic observation	National monitoring network	NIM	Synoptic stations Agro-meteorological stations Climatologic stations Rainfall stations Marine stations Upper-air observation stations	---
Relevant database	Database of national monitoring network	NIM	Climatological data	---
Relevant national monitoring programmes	---	---	---	---

Palestinian Authority

The Palestinian Authority is an observer member of WMO and UNFCCC. The main responsible authorities for meteorological data collection are the Palestinian Meteorological Office (PMO) and the Palestinian Water Authority (PWA). On the basis of the poor information available, the national monitoring network does not seem to be adequate. For instance, the significant uncertainty regarding forecasted precipitation patterns for the eastern Mediterranean and the Middle East is partly attributed to insufficient observational data for Palestine (Mimi ZA, Mason M, Zeitoun M, 2009).

According to a comprehensive study on climate change impacts and adaptation, there is an identified need for the Palestinian Authority to acquire increased capacity for monitoring and modeling rainfall variability and long-term climate change within its territory (Mimi ZA, Mason M, Zeitoun M, 2009). In general, installing a network of meteorological stations for future monitoring of climate change impacts is a priority as there is currently no access to Israeli meteorological data (UNPD, 2010).

Detailed information on database and relevant national monitoring programmes were not available at the time of writing. Only the presence of water quality monitoring programmes in place within PWA could be acknowledged. Furthermore, a drought early-warning system is being developed, which will possibly improve data collection on rainfall and soil moisture (UNDP, 2010).

PALESTINIAN AUTHORITY				
	Description	**Responsible authority**	**Scope**	**Identified gaps**
Systematic observation	National monitoring network	PMO PWA	Meteorological stations Hydrological stations	Limited infrastructure Geographical distribution of stations may be not representative for all Palestinian Territory
Relevant database	Database of national monitoring network	---	---	Data gaps for time series
	Hydrological database	PWA	Hydrological data	Low quality control Obsolete procedures
Relevant national monitoring programmes	----	---	---	---

Main issues regarding national monitoring programmes and database for climate variability and change:

- National monitoring often facing problems with poor or obsolete infrastructure, limited extension of the networks over space and time, lack of coordination between responsible authorities;
- Overall absence of specific national programmes for climate variability and change, or not specifically focused on climate change if implemented;
- Lack of common database between relevant authorities involved in climate monitoring;
- Inadequate, obsolete national database and related collecting and storage procedures;
- Limited institutional capacities for data verification, dissemination and analysis;
- Scarce capabilities for modeling and prediction in the remote sensing sector;
- Lack of funding for staff training;
- General lack of adequate information on systematic observation provided through the UNFCCC National Communications, especially with regard to North African countries reporting.

3.3 Proposal for regional activities

The overview of regional climate monitoring programmes in the Greater Mediterranean Region highlighted that GCOS is a comprehensive system relying on national networks of systematic observations and working through climate-relevant components of existing atmospheric, oceanic and terrestrial monitoring systems. Under the umbrella of G3OS a number of relevant observing programmes and networks involving Mediterranean and North African countries were identified, along with related data archives. Among those programmes, MOON, MedGOOS and MedGLOSS and their expected developments deserve a special attention with a view to supporting the implementation of the ICZM Protocol in Mediterranean coastal countries. Importantly, GCOS has a targeted Regional Workshop Programme for the Mediterranean Basin that has launched a process for strengthening the basic structures and enhancing the capacities for data analysis and prediction in the region.

On the other hand, national assessments revealed an overall insufficient capacity for climate change and variability monitoring in terms of institutions, expertise, infrastructure and facilities. The lack of specific national programmes and the general inadequacy of relevant database for climate change monitoring are particularly evident in North African and East Mediterranean countries. In addition, North Africa shows a remarkable shortage of adequate and complete information on systematic observation at the national scale.

As a conclusion, we believe the establishment of a new regional programme and database for monitoring climate variability and change would be a duplication of efforts for the scientific community involved. Furthermore, given the possible participation of a limited number of Mediterranean countries in the UNEP/MAP full-size project, we do not consider it effectively feasible or cost-effective. Bearing in mind the criteria of minimizing duplication, reducing costs and enhancing coordination, we would rather foresee the possibility of **providing technical assistance and capacity building activities for the implementation of climate observations as well as climate variability and change monitoring in the Mediterranean Basin, with a particular focus on North African and East Mediterranean countries**. **At the national level there are the premises for offering technical assistance for the development and implementation of national monitoring programmes.**

Specific activities in the framework of the full-size project could include:

- **Establishment of designated climate change coordinating units within the countries**, with appropriate operational branches (e.g. dedicated to climate change monitoring and climate change response), involving relevant responsible authorities, ministries and academic/research institutions, to which technical assistance and capacity-building support shall be given, inter alia, for:
    - Developing and implementing national monitoring programmes focused on climate variability and change;
    - Improving data collection, processing and maintenance at the national level;
    - Data rescue at the national level (not only ECVs but also metadata, non-instrumental observations, and phenological data);
    - Improving the quality and accuracy of National Reports to the UNFCCC on the status of systematic climate observations and climate research.
- **Establishment of a web-based regional Information System** within an existing centre/organization that shall contain information on climate change and variability

monitoring and research covering the Greater Mediterranean Region (e.g. involving UNEP INFO/RAC);

- **Establishment of a Mediterranean forum to facilitate region-wide coordination** across all components of climate observing systems, through a series of meetings, workshops and other coordinating activities;
- **Establishment of a platform for exchange and sharing of project expertise** within the larger climate observing community (e.g. GCOS RAP developments);
- **Support the establishment of a potential regional GCOS Lead Centre** in the Mediterranean Basin within an existing institution, to which technical assistance and capacity-building support shall be provided.

3.4 Recommendations

In the context of a general support of the **full implementation of GCOS and the GCOS Regional Action Plan for the Mediterranean Basin** - of utmost importance for the development of regional systematic observation activities focused on climate variability and change - and the enhancement of national capacities for climate monitoring, the following key actions are recommended:

- **Strengthen and sustain oceanographic climate monitoring in the Mediterranean by supporting GLOSS, MedGLOSS, MOON, MedGOOS related ongoing developments and extensions in the Northern African countries;**
- **Ensure the coordination of domestic GCOS activities (such as climate observing, data management and data exchange issues) and provide the interface to the national, regional and international GCOS concerns through nominated GCOS National Focal Points;**
- **Ensure the provision of long-term funding and other resources needed to sustain GCOS stations and related programmes and networks at the national scale, especially in Northern African and East Mediterranean countries;**
- **Ensure the free and unrestricted international exchange of climate system observations and related metadata from GCOS stations and related networks.**

In particular, the following activities are recommended:

- **Establishment of designated climate change coordinating units within the countries, with appropriate operational branches involving relevant responsible authorities, ministries and academic/research institutions, to which technical assistance and capacity-building support shall be given;**
- **Establishment of a web-based regional Information System that shall contain information on climate change and variability monitoring and research covering the Greater Mediterranean Region;**
- **Establishment of a Mediterranean forum to facilitate region-wide coordination across all components of climate observing systems;**
- **Establishment of a platform for exchange and sharing of project expertise within the larger climate observing community;**
- **Support the establishment of a potential regional GCOS Lead Centre in the Mediterranean Basin within an existing institution, to which technical assistance and capacity-building support shall be provided.**

4 OVERVIEW OF EXISTING OBSERVATIONAL DATASETS AND CLIMATE MODELING IN THE MEDITERRANEAN REGION

4.1 Observational datasets for the Mediterranean area

High-quality observational data sets for the Mediterranean area are required in order to both investigate the climate variability and assess the climate change signal on regional scale and to validate and improve the numerical models used to produce simulations and climate change projections. In particular, with the aim of providing a robust detection and attribution of climate trends and assessing the possible change at local scale, long instrumental observational time series with a good spatial distribution are needed.

Within the EU projects ENSEMBLES and CIRCE some substantial work has been done in collecting observational data sets and producing analyses for both atmospheric parameters over the Euro-Mediterranean region (Haylocket al., 2008) and in the Mediterranean Sea (e.g., Adani et al., 2011). In the following, we summarize very briefly the main characteristics and of these datasets, providing also pertinent references. A more detailed review and deeper analysis of data sources is provided in Chapter 5 of the present report.

One of the objectives of the CIRCE project is to provide an analysis and an assessment of the observed past and present climate changes in the Mediterranean area. The detection and attribution of the observed climate trends is based on an extensive analysis of available data sets, both from stations and from gridded sources available for the region. Ulbrich et al. (2011) provide a catalogue of available observational station data and gridded data sets and an evaluation of their basic characteristics. From their work, it appears that station data of near-surface temperature (T2m) and precipitation are available for the second half of the 20th century (or part of it) with a reasonably good spatial distribution in the Mediterranean area. These station records stem from a number of sources and data bases, such as for example the Global Historical Climatology Network (GHCN) (Peterson and Vose, 1997), the European Climate Assessment & Data set (ECA&D) (Klein Tank et al., 2002), the WMO–Initiative on Mediterranean Climate Data Rescue (WMO-MEDARE) (Brunet and Kuglitsch 2008) and the National Meteorological and Hydrological Services (NMHS).

The data are available in form of both daily means and monthly means. In general, the monthly mean values of near surface temperature and precipitation are better spatially distributed and for longer periods in the northwestern shore of the Mediterranean basin. Sparser

data are available from Balkans and Middle East. North Africa exhibits the lowest availability of data, with a number of station time series starting at the beginning of the 20th century, covering a couple of decades, but with no up-dates to present.

The station data of temperature daily means generally have a poorer spatial distribution, they are mostly concentrated in the northern part of the Mediterranean, and with shorter temporal coverage. In North Africa, some daily temperature time series are available from the stations located near Alger and Melilla. Also, Alger is the only Northern African station with daily precipitation data. Most of the series begin in the mid-twentieth century. On the other hand, Turkey is the only country that shows similar distribution and density between the monthly and daily precipitation time series, while Alger is the single Northern African station with daily precipitation data. Most of the series begin in the mid-twentieth century.

Besides observational station data, gridded data of meteorological parameters such as temperature, precipitation or air pressure offer valuable information. Numerous gridded data sets with different temporal (sub-daily to monthly) and spatial resolution (0.25°x0.25° to 5°x5°) can be found and used to characterize the climate of the Mediterranean region, its variability and change. Specifically, gridded data sets covering the Mediterranean basin and the surrounding areas are APRHODITE (E. Mediterranean only, Yatagai et al., 2008), CMAP (Xie and Arkin, 1997), CPC GHCN/CAMS (Fan and van den Dool, 2008), CRUTEM3 (Brohan et al., 2006), CRU TS 3.0 (Mitchel and Jones, 2005), EMULATE (Ansell et al., 2006), E-OBS (Haylock et al., 2008), ERA-40-Reanalysis (Uppala et al., 2005), GPCC V4 (Schneider et al., 2008), HadSLP2 (Allan and Ansell, 2006), JRA-25 Reanalysis (Onogi et al., 2007), NCEP/NCAR-Reanalysis (Kistler et al., 2001), Tremberth's NH (Trenberth and Paolino, 1980), Twentieth Century Reanalysis (V2) (Compo et al., 2010).

The E-OBS (Haylock et al. 2008) data set deserves some specific comment, which can be then easily extended to the others. This is a high-resolution (0.25°x0.25°) European land only daily gridded data set for precipitation and mean, minimum and maximum temperature for the period 1950–2006, which has been created within the ENSEMBLES Project. This data set is unique in its spatial extent, resolution and the use of many more European observing stations than in other European or global sets. An important part of the data set is daily estimates of interpolation uncertainty, provided as standard errors. **Importantly, despite the general good quality of this dataset, the Mediterranean region is not entirely covered, especially in its southern and eastern part.**

In general, the spatially highly resolved gridded datasets are very useful tools for climate and climate change research on regional scale. However, despite the progress made in the past few years, **the quality of the gridded data sets remains problematic especially for areas characterized by complex terrains and morphology as the Mediterranean region**. In fact, the quality of a gridded data set depends strongly on the quality of the input observations and on the adopted morphology scheme used in the interpolation of the data. Recent analyses (e.g., Kuglitsch et al. 2010, 2009) have shown that a large station data time series in the Mediterranean area are characterized by insufficient quality and thus, also on the light of the complexity of the Mediterranean morphology, the gridded datasets have to be used with some cautiousness.

Observations for the Mediterranean Sea

The datasets discussed above are mostly from atmospheric observation. In the Mediterranean Sea observational data sets are also available.

Specifically, the following can be found:

- Satellite Sea-Surface Temperature (SST) data;
- In-situ temperature and salinity profiles;
- Satellite Sea Level Anomalies (SLA) from altimetry.

Time series of SST from satellite observations from 1985 to 2005 are available in form of Optimal Interpolated SST maps (OI-SST; Marullo et al., 2007), while from 2006 to present the SST maps are produced following the Delayed-Time Optimal interpolation technique of Buongiorno-Nardelli et al. (2003). These data area available at a spatial resolution of 1/16°, corresponding to a spatial grid of about 6.7 Km.

The in-situ data set of temperature and salinity vertical profiles is based on the historical data archive of MedAtlas (Maillard et al., 2003) and it contains data from bottles, thermometers, XBT, MBT, and CTD sensors. The MedAtlas dataset spans the period from 1985 to 1999, but can be extended and updated with the data from the Ship Of Opportunity Program (Manzella et al., 2007) and the MedARGO programme (Poulain et al., 2007) for the subsequent period.

Satellite SLA measurements are available from ERS1, ERS2, Envisat, Topex/Poseidon and Jason1 satellite missions. These data and relative corrections are described by Pujol et al. (2005).

Finally, a set of two ocean re-analyses of the Mediterranean Sea circulation based on the above mentioned data has been performed within CIRCE by Adani et al. (2011). The re-analyses

have been performed using different assimilation schemes (a Reduced Order Optimal Interpolation and a three-dimensional variational scheme), providing the status and all the physical parameters of the Mediterranean Sea from 1985 to 2007 with a daily frequency and at spatial resolution of 1/16° (about 6.7 Km).

4.2 Climate models and the Mediterranean region

The first systematic attempt to develop numerical models specifically aimed at producing climate simulations for the Mediterranean region has been performed within the CIRCE EU Integrated Project. Climate simulations at regional scales were also performed in the framework of previous EU Projects, such as for example PRUDENCE and ENSEMBLES, however their interest was more focused on the European continent, whereas the Mediterranean area (especially the southern shore) was only very marginally considered. Furthermore, the climate simulations performed within these projects were carried out with atmospheric only regional models, which did not take into account any air-sea feedbacks. Therefore, concerning the impact of the climate change on the Mediterranean basin, very few studies were specifically dedicated to the Mediterranean Sea case and its possible evolution along the 21st century before the CIRCE project and none of them were a coordinated effort to tackle the uncertainty issue. A pioneering work was done by Thorpe and Bigg (2000) simulating a transient 2xCO2 scenario with a 1/4°-resolution ocean model forced by the air-sea fluxes of a low-resolution IPCC model (2.5°x3.5°). Later, Somot et al. (2006) performed a similar study using a higher-resolution ocean model (1/8°) forced by fluxes coming from a dynamical downscaling (50 km) of an A2 IPCC run. Both studies suggest an increase in the sea surface temperature (SST) and sea surface salinity (SSS), leading to a strong weakening of the Mediterranean thermohaline circulation (MTHC) and a change in the characteristics of the Mediterranean waters outflowing at the Gibraltar Strait. Furthermore, Somot et al. (2006) took into account the climate change impact coming from all the various forcings of the Mediterranean Sea (air-sea fluxes, Atlantic characteristics, river runoff and Black Sea impact) concluding that all of them could be important contributors to the possible evolution of the sea characteristics.

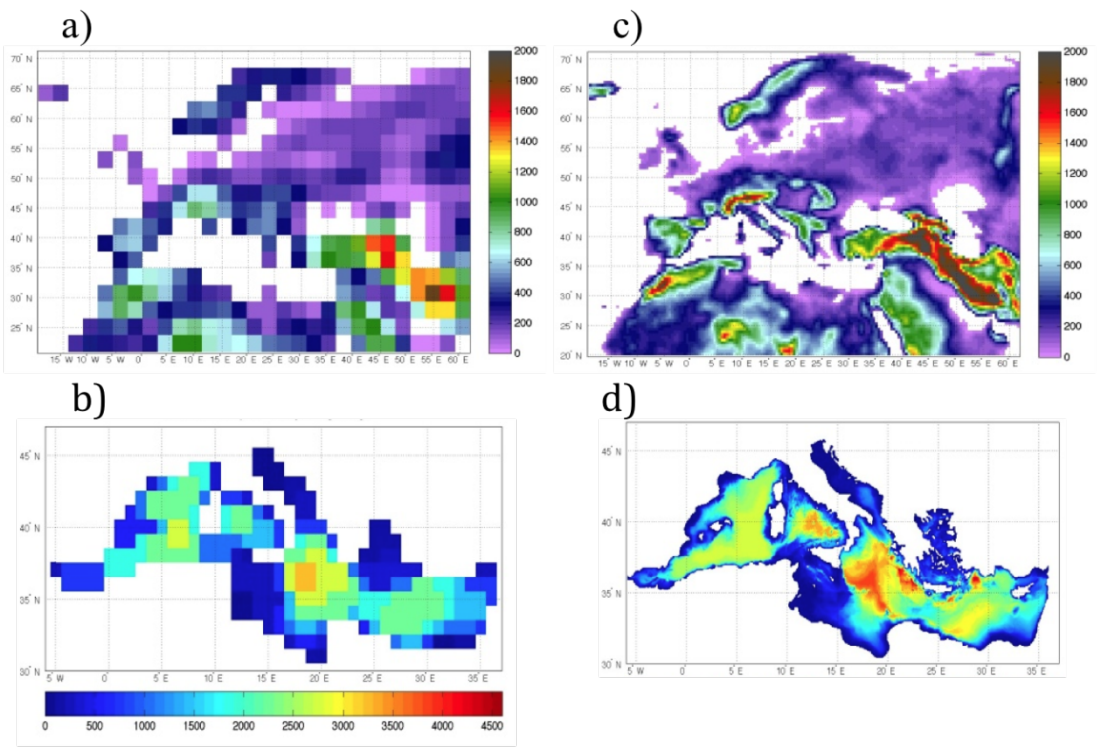

Figure 4.1: Orography of the Euro-Mediterranean region and bathymetry of the Mediterranean Sea as represented in a state-of-the-art global coupled ocean-atmosphere model with horizontal resolution of about 300 Km in the atmosphere and 1º in the ocean (panels a and b), and in the CIRCE models where in most of the models the resolution is higher than 50 Km in the atmosphere and 1/8º in the ocean.

In Figure 4.1, panels a and b show how the Mediterranean Sea and the surrounding mountain chains (Atlas, Alps and Caucasus Mountains) are represented in a global model with a horizontal resolution of about 300 Km in the atmosphere and about 100 Km in the ocean. This is the order of resolution employed, for example, in numerous models used to perform the CMIP3 simulations. It appears evident that several important features, such as for example, the Alps or the coastlines of the Mediterranean Sea itself are only barely resolved. Therefore, these models reproduce the small-scale physical processes that characterize the climatic behaviour of the region very poorly.

On the other hand, the regional models used so far to downscale the global simulations, such as those, for example, employed in the PRUDENCE EU-Project, have a much higher horizontal resolution compared to the CMIP3 models, but they are integrated with non-interactive sea-surface temperature (SST) of the Mediterranean Sea. The SST used to force the regional atmospheric models is prescribed using the fields produced by global low-resolution coupled general circulation models (CGCMs). Therefore, important air-sea feedbacks are totally neglected

in these simulations and, moreover, the lower boundary conditions (SSTs) come from global CGCMs with a very limited capacity to represent the physical processes active in the Mediterranean basin.

4.3 Towards a realistic representation of the Mediterranean region in climate models and simulations

The CIRCE models

The main novel characteristic that distinguishes the CIRCE models from state-of-the-art climate models commonly used to produce scenario simulations is the inclusion of a realistic representation of the Mediterranean Sea into the climate system. So far, in fact, the Mediterranean basin was only crudely represented in the climate simulations. Generally, the global CGCMs have a coarse horizontal resolution, which does not capture and represent the complexity of the geomorphology of the region, with its complex topography and coastlines.

Within the CIRCE project, remarkable efforts have been devoted to enhance the representation of the Mediterranean Sea by developing climate models with ocean components permitting mesoscale circulation features in the Mediterranean basin. The inclusion of the eddy variability tail in the spectrum of the processes resolved by the modelled system represents a particularly relevant step forward with respect to the previous generation of climate models, both global (CMIP3) and regional (PRUDENCE and ENSEMBLES), as these were systematically based on coarse resolution ocean components, leading in turn to an extremely rough representation of the Mediterranean Sea sub-system. Bellucci et al. (2011) have investigated the role of the mesoscale oceanic features on the air-sea interactions over the Mediterranean region. Their analysis highlights the implications deriving from the inclusion of energetic ocean mesoscale structures in the variability spectrum of the coupled ocean-atmosphere system and points to the need for high-resolution ocean components in the development of next generation climate models.

The characteristics of the CIRCE models allow investigating scientific problems for the Mediterranean region, which are usually not easily tractable with climate models with a poor representation of the Mediterranean Sea, such as, for example, an assessment of the possible sea-level change in the Mediterranean basin or changes in the characteristics of the water transport through the Strait of Gibraltar. Therefore, the climate models developed in the framework of

CIRCE already represent a considerable improvement in the modelling of the Mediterranean area, however important further steps can be done as illustrated in the next section.

4.4 Proposal for new modelling activities

Recent works (e.g., Li 2006, Somot et al. 2008, Artale et al. 2010, Gualdi et al. 2011) indicate that high-resolution coupled atmosphere-ocean numerical models are required in order to adequately reproduce the fine and complex processes that characterize the Mediterranean area. In particular, modelling of the Mediterranean region, comprising a high-resolution atmospheric model (~10 Km) coupled with a high-resolution Mediterranean Sea model (~7 km) would allow to tackle important scientific problems, such as, for example, sea-level change of the Mediterranean Sea or the changes in the occurrence of extreme events (e.g., intense cyclones or Medicanes).

For the atmospheric component, a horizontal high-resolution is required in order to reproduce the small-scale processes related to the complex physiography of the region, such as the orographic precipitation and cyclogenesis. Furthermore, a well-resolved non hydrostatic atmospheric dynamics (~10 Km) is also required to represent those extreme events that have a strong impact on coastal areas, such as the intense, tropical-like cyclones also known as Medicanes (e.g., Davolio et al., 2009; Moscatello et al., 2008). In the land, a proper representation of the evolution of the soil moisture and of the runoff (with river catchments and proper treatment of the discharge to the ocean) is needed in order to provide a realistic representation of the hydrologic cycle.

In order to provide a robust assessment of the possible variations in the Mediterranean sea level, a realistic simulation of the various components of the Mediterranean Sea water budget is necessary. Specifically, the climate models should include a fully interactive model of rivers and river discharge into the ocean. The domain should be such as to include all of the important components of the Mediterranean Sea water budget. Specifically, the Black Sea and its interaction with the Aegean Sea, through the Dardanelles, should be properly represented especially for its contribution of freshwater to the Mediterranean Sea. A few examples of how the contribution of the Black Sea can be included into climate modelling of the Mediterranean area can be found in Gualdi et al. (2011). Furthermore, a realistic representation of the interaction between Mediterranean Sea and Atlantic Ocean is also required. In particular, the possible

changes in the amount and in the characteristics of the water (temperature and salinity) exchanged between Mediterranean and Atlantic due to changes in the net water transport through the Strait of Gibraltar have to be taken into account properly.

Coupled atmosphere-ocean models with spatial resolutions ranging between 7 and 14 Km over the Mediterranean area will be generally able to successfully reproduce most of the physical mechanisms that govern the climate of the region and its variability (Li, 2006). **However, though these resolutions are enough to adequately investigate and describe the climate variability and the climate change signal on regional scale, they are still too coarse to produce detailed information to be used in impact models, especially when dealing with problems concerning the possible impacts on the Mediterranean Sea coasts.** To this aim, much finer resolutions are required, especially in the ocean. A possible way to address this issue is the nesting of (relocatable) limited area models, with the aim of having high resolutions (10 to 100 m) in specific areas of the domain, only there where such a fine detailing is actually needed. Specifically, an atmospheric model with horizontal resolution fine enough to represent realistic features of the Mediterranean region will be coupled to a suite of ocean model that will allow the telescoping zoom of the coastal zone under study. A global model of the Mediterranean Sea will provide the boundary condition to a shelf model (1-2 km) resolution that can be coupled to a very high resolution (of the order of 100m) model of the coastal zone up to the penetration into bays and rivers. The suite of models would allow the integrated assessments of climate change scenarios over the coastal environment considering the full set of interaction between the changes in the precipitation caused by climate change, the changes in the river catchment and the interaction with the near coastal region and the open ocean. System of this type have been realized and applied in the Mediterranean and they can be relocated to other areas of the Mediterranean Sea.

Even if the high level of spatial definition in the area of interest is reached by using regional (limited area) models, these models need lateral boundary conditions that must be provided by global climate models able to represent a realistic variability. Therefore, also the global numerical models must be implemented with resolutions high enough (at least 100 Km and finer) to provide a realistic representation of the main modes of large-scale variability (Gualdi et al. 2003 and 2005, and Navarra et al., 2008).

4.5 Recommendations

The following actions are recommended:

- **Implement coupled atmosphere-ocean models with a high resolution (7-10 Km) in the Mediterranean basin able to reproduce the small scale processes related to the complex physiography of the region;**
- **Include a realistic representation of the various components of the Mediterranean Sea water budget in climate models: interactive river runoff and discharge, Black Sea outflow;**
- **Implement a suite of ocean model that will allow the telescoping zoom of specific coastal areas under study. A global model of the Mediterranean Sea will provide the boundary condition to a shelf model (1-2 km) resolution that can be coupled to a very high resolution (of the order of 100m) model of the coastal zone up to the penetration into bays and rivers.**
- **The regional models of the Mediterranean Sea should be nested in a high-resolution global model (finer than 100 Km) able to provide a realistic representation of the main modes of large-scale variability.**

5 THE INDICATORS IN USE FOR MONITORING AND PREDICTIONS OF CLIMATE VARIABILITY AND CHANGE IN THE MEDITERRANEAN REGION

5.1 Introduction

Climate change and variability indicators and in general any environmental indicators[13] remain an essential support tool for science studies and policy across the world. "*In effect, statistical indicators are important for designing and assessing policies aiming at advancing the progress of society, as well as for assessing and influencing the functioning of economic markets. Their role has increased significantly over the last two decades. This reflects improvements in the level of education in the population, increases in the complexity of modern economies and the widespread use of information technology...*" (Stiglitz Report).

Box 5.1: Climate system, climate change and variability definitions

Here we used the terminology as defined in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC).

Climate system

The climate system is the highly complex system consisting of five major components: the *atmosphere*, the *hydrosphere*, the *cryosphere*, the land surface and the *biosphere*, and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of *external forcings* such as volcanic eruptions, solar variations and *anthropogenic* forcings such as the changing composition of the atmosphere and *land use change*.

Climate change

Climate change refers to a change in the state of the *climate* that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or *external forcings*, or to persistent *anthropogenic* changes in the composition of the *atmosphere* or in *land use*.

Climate variability

Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the *climate* on all *spatial and temporal scales* beyond that of individual weather events. Variability may be due to natural internal processes within the *climate system* (*internal variability*), or to variations in natural or *anthropogenic external forcing* (*external variability*).

[13] An ***environmental indicator*** is a numerical value that helps provide insight into the state of the environment or human health. Indicators are developed based on quantitative measurements or statistics of environmental condition that are tracked over time. Environmental indicators can be developed and used at a wide variety of geographic scales, from local to regional to national levels. By monitoring the environment using indicators, EPA can better share meaningful environmental information with the public, and can help ensure that high-quality environmental decisions are made by EPA, its partners, and the public (Environmental Protection Agency, USA) *(http://www.epa.gov/indicator/whatIndicator.html)*

In addition to scientific research, the **climate change and variability (CCV) indicators** are used also in relation to policy making for three main purposes:

1. To provide information on climate related issues and problems in order to enable policy-makers to evaluate their seriousness;
2. To support policy development by identifying key factors that cause pressure on the climate system;
3. To monitor the effect of climate policy responses.

Furthermore the CCV indicators are important tools to raise public awareness on climate issues. At the present time providing information on climate driving forces, impacts and policy responses is a common used strategy to strengthen public support for policy responses.

In general most sets of environmental indicators used by nations and international bodies are based on the **DPSIR framework** or a subset of it. The DPSIR approach is a system analysis dealing with the relations between the environmental system and the human system. Following this approach for climate indicators: the socio-economic developments exert pressure on the environment (hence including the climate system) and as a consequence the State of the environment changes and this change produce Impacts on different sectors/systems such as ecosystems, human health, human settlements and finally all this may causes a societal Response that feeds back on the Driving forces or on the impacts by means of adaptation (see Box 5.2).

Box 5.2: DPSIR framework

DPSIR is a general framework for organising information about state of the environment. The idea of the framework was however originally derived from social studies and only then widely applied internationally, in particular for organising systems of indicators in the context of environment and, later, sustainable development. The framework assumes cause-effect relationships between interacting components of social, economic, and environmental systems, which are

- **D**riving forces of environmental change
- **P**ressures on the environment
- **S**tate of the environment
- **I**mpacts on population, economy, ecosystems
- **R**esponse of the society

This DPSIR approach is quite useful for policy purpose in describing the relationship between the origins and consequences of environmental problems.

In our case a general typology classification of the CCV indicators keeping in mind the DPSIR approach can be applied. This classification includes three groups addressing the following questions:

1. What is happening in the climate system and the humans?
2. Does it matter?
3. Are we improving?

The first question is addressed by the **Descriptive indicators**, which describe the present and past state of the climate system through the usage of observations and the potential futures of the climate system through the usage of outcomes from climate scenario simulations in a particular geographical area. These descriptive indicators can include:

- *Driving forces indicators* describing the socio/economic developments producing the anthropogenic component of the CCV.
- *Pressure indicators* describing developments in release of substance (emissions), the use of land (e.g. greenhouse gas emissions, aerosol emissions, amount of land usages).
- *State indicators* describing the quality and quantity of climatic variables (such as temperature, precipitation), biological variables (such as fisheries) and chemical variables (such as atmospheric and marine GHG concentrations).
- *Impact indicators* describing the climate change impacts in the different systems/sectors;
- *Response indicators* describing the responses by groups of stakeholders or institutions in society as well as government measures to prevent, compensate or adapt to climate change impacts.

The second question is addressed by the **Performance indicators**, which compare the present climate conditions with a specific set of reference conditions. In other words they measure the gap between the current climatic state and the desired situation. In general the governments can develop performance indicators for monitoring their progress toward a climate target. These indicators can concern reference conditions/targets to national policy targets or international policy targets.

The third question is addressed by the **Efficiency indicators***,* which provide information regarding the efficiency of products and process, such as the level of GHG emissions generated by a unit of Gross Domestic Product (GDP) in a country.

5.2 Indicators for southern Europe and the Greater Mediterranean Region

For the purpose of this study we will focus on the climatic descriptive indicators, which will be useful for a future ICZM Protocol for the Mediterranean. These indicators need to be selected due to their measurability, their policy relevance, and their data availability (also in time) over the Greater Mediterranean Region (GMR) i.e. the region comprising the Mediterranean Sea and the surrounding areas in Europe, North Africa and Asia.

The main recent indicator-based assessment reports covering the European area and partly the GMR are the Chapters "*Europe*" and "*Africa*" of IPCC AR4 WGII (Parry et al., 2007) and the Joint EEA-JRC-WHO Report "Impacts of Europe's changing climate – 2008 indicator-based assessment" (2008). About forty indicators for observed and projected impacts in different categories have been analyzed in the EEA/JRC/WHO report (2008) and they will be updated for a new EEA report to be published in 2012. Both reports have shown for southern Europe and the GMR the following past and projected impacts and effects on sectors (see Table 5.1 and 5.2):

- Increase of surface air temperature,
- Decrease of annual precipitation,
- Decrease of annual river flow,
- Increase of water demand for agriculture,
- Higher risk of desertification,
- Increase of forest fires,
- Decrease of crop yields,
- Increase of mortality due to heat waves,
- Decrease of summer tourism,
- Decrease of risk of biodiversity loss.

In particular, the Joint EEA-JRC-WHO Report (2008) highlighted for North and South Europe (and the Greater Mediterranean Region) key improvements needed to increase the quality of assessment of climate change and its impacts, such as:

1. Need to enhance the usage of longer time series of observations and re-analyses of physical climate change indicators or ECV (Essential Climate Variables) as defined by GCOS (Global Climate Observing System) with higher spatial resolution;

2. Need of scenarios (including probabilistic) of physical climate change at higher spatial resolution, for the next decades (not only e.g. 2100), and at the scales of the river basin level along with an estimation of their uncertainties;
3. Need of enhancing the observation systems for long term monitoring of impacts on biodiversity and ecosystems (marine, freshwater, terrestrial including soil) and human health and need of development of harmonised definitions for indicators consistent with other initiatives.

Indicators	Key findings in the IPCC AR4 (2007)
Temperature	*Maximum summer temperatures are likely to increase more than the average in **southern** and central Europe.* ***WGI, Chapter 11*** *In this century, the warming is projected to continue at a rate somewhat greater than its global mean, with the increase in 20-year mean temperatures (from its values in 1980 to 1999) becoming clearly discernible within a few decades. Under the A1B scenario, the simulated area and annual mean warming from 1980 to 1999 to 2080 to 2099 varies … from 2.2°C to 5.1°C in SEM. The warming … in the **Mediterranean area** large in summer.* ***WGI, Chapter 11,*** *The warming is greatest over … **Southern Europe** in summer (June to August: JJA) (Giorgi et al., 2004). Results using two regional climate models under the PRUDENCE project (Christensen and Christensen, 2007) showed a larger warming in winter than in summer in northern Europe and the reverse in **southern** and central Europe. A very large increase in summer temperatures occurs in the **southwestern parts of Europe**, exceeding 6°C in parts of France and the **Iberian Peninsula** (Kjellström, 2004; Räisänen et al., 2004; Christensen and Christensen, 2006; Good et al., 2006).* ***WGII - Chapter 12*** *The yearly maximum temperature The yearly maximum temperature is expected to increase much more in **southern** and central Europe than in northern Europe (Räisänen et al., 2004; Kjellström et al., 2007). Kjellström (2004) shows that, in summer, the warming of large parts of central, **southern** and eastern Europe may be more closely connected to higher temperatures on warm days than to a general warming.* ***WGII - Chapter 12***
Precipitation	*Annual precipitation is very likely to … decrease in most of the **Mediterranean area**.* ***WGI - Chapter 11*** *The annual number of precipitation days is very likely to decrease in the **Mediterranean area**.* ***WGI - Chapter 11*** *Mean annual precipitation is projected to increase in the North and decrease in **the South**.* ***WGII - Chapter 12*** *In the **Mediterranean area**, yearly precipitation trends are negative in the east, while they are non-significant in the west (Norrant and Douguédroit, 2006).* ***WGII - Chapter 12***
Runoff	*Summer low flow may decrease by … up to 80% in some rivers in **southern Europe** (Santos et al., 2002).* ***WGII - Chapter 12*** *Arnell (2004) estimated a 40 to 50% reduction in runoff **in southern Europe** by the 2080s (associated with a 2 to 3°C increase in global mean temperature).* ***WGII - Chapter 19***
Droughts	*Risk of summer drought is likely to increase … in the **Mediterranean area**.* ***WGI - Chapter 11*** *… **southern and southeastern Europe** show significant increases in drought frequencies.*

	WGII - Chapter 3 *Warmer, drier conditions will lead to more frequent and prolonged droughts, as well as to a longer fire season and increased fire risk, particularly in the* ***Mediterranean region.*** ***WGII - Chapter 12*** *Regions of constant or reduced precipitation are very likely to experience more frequent and intense droughts, notably in* ***Mediterranean-type climates*** *…* ***WGII - Chapter 19***
Water resources	*Prominent regions, with a rather strong agreement between models, of decreasing runoff (by 10 to 30%) include the* ***Mediterranean****,...* ***WGII - Chapter 3***
Heat waves and extremes	*Along with the overall warming and changes in variability, heat waves are very likely to increase in frequency, intensity and duration (Barnett et al., 2006; Clark et al., 2006; Tebaldi et al., 2006). Conversely, the number of frost days is very likely to decrease (Tebaldi et al., 2006).* ***WGI - Chapter 11*** *The yearly maximum temperature is expected to increase much more in* ***southern*** *and central Europe than in northern Europe (Räisänen et al., 2004; Kjellström et al., 2007).* ***WGII - Chapter 12*** *Christensen and Christensen (2003), Giorgi et al. (2004) and Kjellström (2004) all found a substantial increase in the intensity of daily precipitation events. This holds even for areas with a decrease in mean precipitation, such as … the* ***Mediterranean****. Impact over the* ***Mediterranean region*** *during summer is not clear due to the strong convective rainfall component and its great spatial variability (Llasat, 2001).* ***WGII - Chapter 12*** *Summer tourism in the* ***Mediterranean*** *but an increase in spring and perhaps autumn (Amelung and Viner, 2006). Maddison (2001) has shown that* ***Greece*** *and* ***Spain*** *will experience a lengthening and a flattening of their tourism season by 2030.* ***WGII - Chapter 12***
Coastal zones and wetlands	*Regionally, losses would be most severe on … the* ***Mediterranean****.* ***WGII - Chapter 6*** *Inland waters in southern Europe are likely to have lower volume and increased salinisation (Williams, 2001; Zalidis et al., 2002). Many ephemeral ecosystems may disappear, and permanent ones shrink (Alvarez Cobelas et al., 2005).* ***WGII - Chapter 12***

Table 5.1: Key information on climate change and climate change impacts (related to the needs of this report) over Southern European area and Mediterranean area from the AR4 Report (2007) of IPCC (www.ipcc.ch).

Indicators	Key findings in the EEA Report (2008)
Surface air Temperature	*Europe has warmed more than the global average. The annual average temperature for the European land area up to 2007 was 1.2 °C above pre-industrial levels, and for the combined land and ocean area 1 °C above.* *The annual average temperature is projected to rise this century by 1–5.5 °C (best estimate) with the largest warming over …* ***southwestern*** *and* ***Mediterranean Europe*** *in summer.*
Precipitation	*Annual precipitation trends in the 20th century showed … a decrease in some parts of* ***southern Europe*** *(up to 20 %).* *…* ***southern Europe*** *… was characterized by drier winters.* *Models project … whereas many parts of Europe may experience dryer summers. But there are uncertainties in the magnitude and geographical details of the changes.*
Temperature extremes	*… warm extremes have become more frequent. The frequency of hot days almost tripled between 1880 and 2005.*

	*For Europe as a whole heat waves are projected to increase in frequency, intensity and duration, whereas winter temperature variability and the number of cold and frost extremes are projected to decrease further. The European regions projected to be most affected are the **Iberian Peninsula**, … the **eastern Adriatic seaboard**, and **southern Greece**.*
Precipitation extremes	*For Europe as a whole, the intensity of precipitation extremes such as heavy rain events has increased in the past 50 years, even for areas with a decrease in mean precipitation such as … the **Mediterranean**.* *For Europe as whole, heavy precipitation events are projected to continue to become more frequent.* *Dry periods are projected to increase in length and frequency, especially in **southern Europe**.*
Sea surface temperature	*Sea surface temperature in European seas is increasing more rapidly than in the global oceans. The rate of increase is … lower in the **Mediterranean Sea**.* *The rate of increase in sea surface temperature in all European seas during the past 25 years has been about 10 times faster than the average rate of increase during more than the past century.* *The rate of increase observed in the past 25 years is the largest ever measured in any previous 25 year period.*
Sea level rise	*In Europe rates of sea level rise (SLR) ranged from – 0.3 mm/year to 2.8 mm/year.* *An additional 1.6 million people living in Europe's coastal zones could experience coastal flooding by 2080.*
River flow	*Over the 20th century, annual river flows showed … a slightly decreasing trend in **southern parts of Europe**. These changes are linked to observed changes in precipitation patterns and temperature.* *Annual river flow is projected to decrease in **southern** and **southeastern Europe** … but absolute changes remain uncertain.* *Summer flows are projected to decrease in most of Europe, also in regions where annual flows will increase.* *Regions in **southern Europe** which already suffer most from water stress are projected to be particularly vulnerable to reductions in water resources due to climate change. This will result in increased competition for available resources.*
River flow drought	*Europe has been affected by several major droughts in recent decades, such as … the 2005 drought in the **Iberian Peninsula**.* *Despite the absence of an overall trend in Europe as a whole, climate change has probably increased the frequency and/or severity of droughts in some regions.* *Climate change is projected to increase the frequency and intensity of droughts in many regions of Europe as a result of higher temperatures, decreased summer precipitation, and more and longer dry spells.* *The regions most prone to an increase in drought hazard are **southern** and **south-eastern Europe** …*
Soil erosion by water	*An estimated 115 million hectares, 12 % of the total EU land area, are subject to water erosion.* *The projected changes in the climate during the 21st century, with increased variations in rainfall pattern and intensity, will make soils more susceptible to erosion.* *The off-site effects of soil erosion will increase with climate change and related changes in rainfall pattern and intensity.*
Water requirement	*A significant increase in water demand (50–70 %) occurred mainly in **Mediterranean areas** between 1975 and 2006.*

Table 5.2: Key information on climate change and climate change impacts (related to the needs of this report) over Southern European area and Mediterranean area from the EEA/JRC/WHO report (2008) (http://www.eea.europa.eu/publications/eea_report_2008_4).

In addition, IPCC AR4 WGII (Parry et al., 2007) in its Executive Summary of Chapter 6 "*Coastal systems and low-lying areas*" highlighted policy-relevant messages that are important to low-lying coastal areas globally (see Box 5.3).

Box 5.3: Policy-relevant messages on coastal areas

1. Coasts are experiencing the adverse consequences of hazards related to climate and sea level (very high confidence).
2. Coasts will be exposed to increasing risks, including coastal erosion, over coming decades due to climate change and sea-level rise (very high confidence).
3. The impact of climate change on coasts is exacerbated by increasing human-induced pressures (very high confidence).
4. Adaptation for the coasts of developing countries will be more challenging than for coasts of developed countries, due to constraints on adaptive capacity (high confidence).
5. Adaptation costs for vulnerable coasts are much less than the costs of inaction (high confidence).
6. The unavoidability of sea-level rise, even in the longer-term, frequently conflicts with present-day human development patterns and trends (high confidence).

5.3 Data sources for indicators for southern Europe and the Greater Mediterranean Region

5.3.1 Climatic and marine indicators

As anticipated in Chapter 4 of this report, we can consider two different types of data: the observational station datasets and the gridded datasets. Here we provide a more detailed review of the datasets available for the GMR.

Observational station datasets

Several daily and monthly temperature and precipitation data are available for the GMR with most of them covering the second half of the twentieth century and having different sources (see Table 5.1).

It is important for the purpose of this study to highlight the *Mediterranean climate DAta Rescue (MEDARE) initiative*, started from the World Meteorological Organization (WMO) aimed to develop, consolidate and progress climate data and metadata rescue activities across the GMR in order to develop comprehensive high quality instrumental surface climate datasets. This is achieved by fostering collaboration among Mediterranean climate related institutions/agencies and National Meteorological and Hydrological Services (NMHS), by promoting capacity building

and training activities addressed for developing countries in the GMR, and by mobilising resources and efforts at the national, regional and international levels in support of Data Rescue and Homogenisation (DARE&H) of long climate records over the GMR and undertake specific national and transnational DARE projects (Fig. 5.1).

Source	*Type of data*	*Web-site*	*Reference*
MEDARE (MEditerranean climate DAta Rescue)	Essential Climate Variables (ECVs) of Global Climate Observing System (GCOS).	http://www.omm.urv.cat/MEDARE/index.html	Brunet and Kuglitsch (2008)
Global Historical Climatology Network (GHCN-Monthly and GHCN-daily)	Global daily data of temperature (max, min and mean) and precipitation from over 43000 stations (about 8500 of which are regularly updated with observations from within the last month) for a period starting also from the 19th century.	http://www.ncdc.noaa.gov/oa/climate/ghcn-daily/	Peterson and Vose (1997)
European Climate Assessment & Data set (ECA&D)	Daily data of temperature (max, min and mean), Sunshine, precipitation, Sea level pressure, humidity, wind and cloud cover at 3643 meteorological stations throughout Europe and the Mediterranean.	http://eca.knmi.nl/	Klein Tank et al. (2002)
MedGLOSS	Near Real Time sea level data.	http://medgloss.ocean.org.il/	
MED-HYCOS (Mediterranean Hydrological Cycle Observing System)	Network of hydrometeorological real time or near real time data collecting platforms (DCPs) on the main rivers of the Mediterranean catchments. The Data Collecting Platforms Network of about fifty stations is composed of Data Collecting Platforms (DCPs) installed in Albania, Bosnia, Bulgaria, Cyprus, Croatia, Malta, Slovenia, Morocco, Tunisia, Turkey, Jordan, Lebanon, Macedonia, and Palestinian Territories. Furthermore, a secondary network of Near Real Time Stations (NRT), established in Albania, Bulgaria, Spain, France, Italy, Greece, Slovenia and Romania, has completed this network.	http://medhycos.mpl.ird.fr/	
AMHY FRIEND (Alpine and Mediterranean Hydrology)	Hydrological stations data: such as low flows, floods, variability of regimes, rainfall/runoff modelling, processes of streamflow generation, sediment transport, snow and glacier melt, climate change and land-use impacts.	www.camilab.unical.it/sito_amhy/home_page.htm	

Table 5.3: Sources and references of the main observational station datasets (temperature and precipitation) for GMR.

In general these three observational station datasets show in the GMR a good spatial distribution for at least the last half century and longer time series are located in the northern

Mediterranean basin, while shorter data series are located in North Africa. In particular, the daily temperature network (Fig. 5.3), comparing to the monthly, shows a lower density and shorter temporal coverage (174 stations) and show higher density again in the northern basin. The rest of the GMR shows a significantly sparser coverage, in particular in North Africa.

In addition several observational gridded data sets are available from the National Meteorological and Hydrological Services (NMHSs) in the area.

Figure 5.1: The present MEDARE station dataset (from http://app.omm.urv.cat/urv/).

Figure 5.2: Map of MEDGLOSS stations (from http://medgloss.ocean.org.il/).

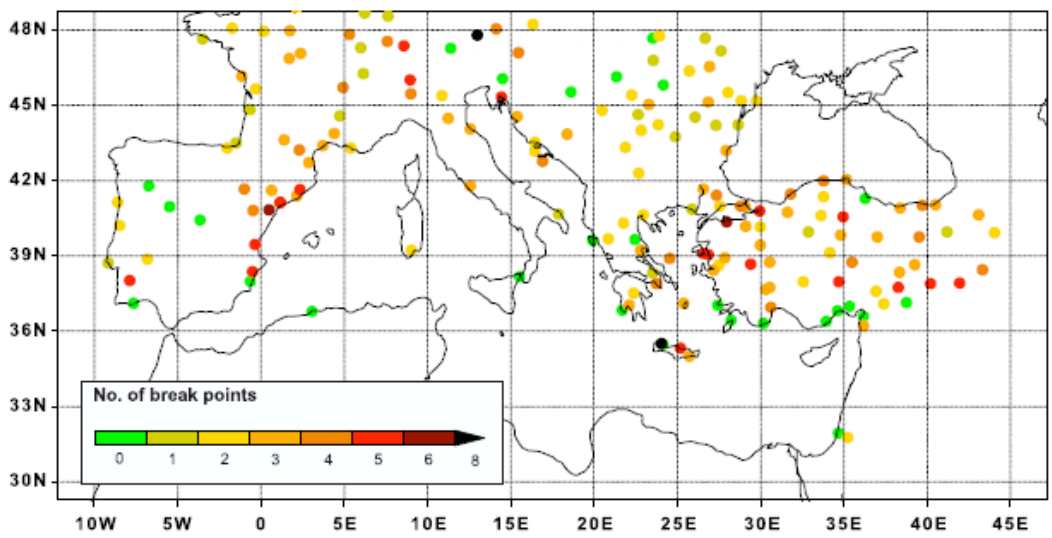

Figure 5.3: The 174 daily summer maximum temperature series in the Greater Mediterranean Region covering the last 50–100 years used in *Kuglitsch et al. (2009) including data* from the ECA&D (*Klein Tank et al., 2002*), MEDARE (*Brunet and Kuglitsch, 2008*) and other stations from countries.

These station data can show less precise values in the early 20th century because there were fewer stations collecting measurements at the time, also can be affected from changes over time of measurement instruments and methods (for example, the time of day measurements are taken) and from changes in the locations of the stations, but in general the overall trends are still reliable.

It is important also to highlight some networks concerning the hydrological data:

- The **MED-HYCOS** network of hydrological stations covering also the southern Mediterranean countries, which include a real-time *Data Collecting Platform (DCP)* network on major rivers, development of a Hydrological Information System, and training activities.
- The **AMHY FRIEND** (Alpine and Mediterranean Hydrology), part of FRIEND (Flow Regimes from International Experimental and Network Data) research programme (international study of regional hydrology sponsored by UNESCO's International Hydrological Programme – IHP), which cover various hydrological stations data, such as low flows, floods, variability of regimes, rainfall/runoff modelling, processes of streamflow generation, sediment transport, snow and glacier melt, climate change and land-use impacts.

Gridded datasets

Also several gridded climate data for climate and marine variables/parameters (see Table 5.2) are available in the GMR at different temporal (sub-daily to monthly) and spatial resolution.

Sources	*Type of data*	*Web-site*	*References*
APRHODITE (Eastern Mediterranean only) – **V1003R1 version**	Daily precipitation data at 0.5° degree resolution for 1951-2007	www.chikyu.ac.jp	Yatagai et al. (2008)
CMAP (CPC Merged Analysis of Precipitation)	Monthly precipitation values on 2.5 degree global grid and pentad precipitation values for 1979-2009	www.esrl.noaa.gov/psd/data/gridded/data.cmap.html	Xie and Arkin (1997)
CPC GHCN/CAMS	Monthly Global land-only Surface Air Temperature Data Set at 0.5 degree from 1948-present. This product is an analysis based upon station data from both the Global Historical Climatology Network version 2 (GHCN) and the Climate Anomaly Monitoring System (CAMS).	ftp.cpc.ncep.noaa.gov/wd51yf/GHCN_CAMS	Fan and van den Dool (2008)
CRUTEM3	Monthly gridded dataset of global historical land surface temperature anomalies since January 1850, on a 5-degree grid.	hadobs.metoffice.com/crutem3	Brohan et al. (2006)
CRU TS 3.0	Monthly global gridded data at 0.5 degree for 1901-2006 of cloud cover, diurnal temperature range, frost day frequency, precipitation, daily mean temperature, monthly average daily maximum temperature, vapour pressure, wet day frequency.	badc.nerc.ac.uk/view	Mitchel and Jones (2005)
EMULATE (European and north Atlantic daily to multidecadal climate variability)	Daily 5-degree data of mean-sea-level pressure (MSLP) for the North Atlantic and Europe for 1850-2003.	www.cru.uea.ac.uk/cru/projects/emulate	Ansell et al. (2006)
E-OBS	Daily gridded data for daily mean temperature, daily minimum temperature, daily maximum temperature and daily precipitation sum in Europe at 0.25-degree resolution for 1950-2009.	eca.knmi.nl/download/ensembles/download.php	Haylock et al. (2008)
ERA-40-Reanalysis	Reanalysis atmospheric data from ECMWF for 1957 to mid-2002 at 2.5° x 2.5° and at higher spectral resolution TL159	www.ecmwf.int/products/data/archive/descriptions/e4/	Uppala et al. (2005)
GPCC V4	Monthly Mean Precipitation for 1950-present at 1.0 degree global grid and 0.5 degree global grid	www.esrl.noaa.gov/psd/data/gridded/data.gpcc.html	Schneider et al. (2008)
HadSLP2 (Hadley Centre Sea Level Pressure dataset)	Monthly mean sea level pressure (MSLP) data (combination of monthly globally-complete fields of land and marine pressure observations) on a 5 degree grid for 1850-2004	hadobs.metoffice.com/hadslp2	Allan and Ansell (2006)
JRA-25 Reanalysis (Japan Meteorological Agency)	Global reanalysis meteorological data for 1979-2004 at T106L40 spectral resolution	jra.kishou.go.jp/JRA-25/index_en.html	Onogi et al. (2007)
NCEP/NCAR Reanalysis	Global reanalysis of 4-times daily, daily and monthly meteorological values for 1948-present at 2.5-degree resolution and monthly means, derived from data for years 1968 – 1996.	www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html	Kistler et al. (2001)
Twentieth Century Reanalysis(V2)	6-hourly,daily average and monthly meteorological values for 1871-2008 at 2.0 degree resolution	www.esrl.noaa.gov/psd/data/gridded/data.20thC_ReanV2.html	Compo et al. (2010)
MyOcean	MyOcean is the implementation project of the GMES Marine Core Service, aiming at deploying the first concerted and integrated pan-European capacity for Ocean Monitoring and Forecasting.	www.myocean.eu	

	MyOcean Service provides the best information available on the ocean based on the combination of space and in situ observations, and their assimilation into 3D simulation models: temperature, salinity, currents, ice extent, sea level, primary ecosystems,… Maritime security, oil spill prevention, marine resources management, climate change, seasonal forecasting, coastal activities, ice monitoring, water quality and pollution are some of the targeted applications of MyOcean.		
E-SURFMAR	The Surface Marine observation programme of EUMETNET (E-SURFMAR) was established during 2003 as an optional element of the EUCOS Programme. The programme consists of fixed moored buoys, drifters and VOS in the North Atlantic and Mediterranean as the European Met Services contribution to the global observing system JCOMM programmes. Data are freely made available on the WMO GTS with no restriction on use.	www.eucos.net	
MERCATOR OCEAN	Mercator Ocean disseminates standard grids data file products, netCDF format, COARDS convention. These products are reinterpolation on standard grids from native model grids. Grids are cut into several areas. Each area is reinterpolated on a given resolution grid. This resolution is selected considering both the ocean physics relevant representation (as a function of the area size) and dissemination and storage cost. Marine data are: temperature, salinity, heat content, density ocean mixed layer thickness, temperature ocean mixed layer thickness, sea surface height.	www.mercator-ocean.fr	
SEADATANET	SEADATANET has developed an efficient distributed Marine Data Management Infrastructure for the management of large and diverse sets of data deriving from in situ and remote observation of the seas and oceans. SeaDataNet develops basic products that consist mainly of gridded fields of environmental parameters to estimate their mean, seasonal variability and interannual trend. Data for the Mediterranean Sea are: monthly climatological (1998-2007) sea surface chlorophyll concentration, monthly climatological (1985-2007) SST, seasonal climatologies of sea level anomalies and 4D analyses of nitrate, Silicate, salinity, Oxygen, Phosphate.	www.seadatanet.org	
MOON (Mediterranean Ocean Observing Network)	MOON is the coordinating body of the EuroGOOS Mediterranean Task Team and it has developed a MoU between several operational and research agencies. MOON main objectives are to: a) consolidate and expand the Mediterranean Sea concerted monitoring and forecasting systems, b) co-ordinate, improve and harmonise observation and information systems c) increase the quality of, and harmonise user-oriented operational products,	www.moon-oceanforecasting.eu	

	d) co-operate with UNEP-MAP and other relevant bodies acting at regional level e) encourage Mediterranean scientific research on monitoring/forecasting activities and their link with operational oceanographic services f) facilitate the availability and dissemination of long term high quality data required to advance the scientific understanding of the Mediterranean Sea. MOON is established with full recognition of the experience by the existing operational and pre-operational systems at national and regional and global scales (MFSTEP, MERCATOR, ADRICOSM, POSEIDON, CYCOFOS, ESEOO,etc).		
JERICO (Towards a Joint European Research Infrastructure network for Coastal Observatories)	JERICO is an FP7 project that aims at setting up a European infrastructure for coastal observations for operational oceanography. Main focus is on coastal automatic platforms that provide continuous measurements in real and near real time (R/V, fishing boats, ships of opportunity, gliders, HF radars). One important part of the project is on sharing best practices at European level. It will start mid 2011 with a 4 year duration. The data will be provided in real time to GMES via MyOcean in-situ TAC and the long-term preservation will be done through SeaDataNet.	Not yet	
TOPEX/Poseidon, TOPEX/Poseidon (Reprocessed), TOPEX/Poseidon Tandem Mission Jason-1, Jason-2/OSTM, ERS-1 phases C & G, ERS-2 phase A, Envisat	Satellite altimeter data for estimation of sea level for different time period spanning from November 1986 up to March 2010.		
CMIP3 (Coupled Model Intercomparison Project)	Monthly and daily climate models data from 25 climate models such as: atmosphere data, ocean data, extremes, radiative forcing data and sulphate aerosol data.	www-pcmdi.llnl.gov/about/index.php	
CIRCE (Climate Change and Impact Research: the Mediterranean Environment)	Climate global and regional model data (simulation of 20th century and A1B scenarios of first half of 21st century) focused for the GMR.	www.circeproject.eu	RACCM Report (in press)

Table 5.4: Gridded datasets available for the Greater Mediterranean Region.

For areas like the GMR with complex orography and coastlines the usage of spatially highly resolved gridded datasets is a very adequate tool for climate research. On the other hand these gridded datasets have to be used with cautiousness, being their quality highly dependent on the quality of the input observation time series and on the adopted morphology scheme (Kuglitsch et al. 2010, 2009).

Model climate projections data

In recent past, few projects have developed scenario simulations aimed at quantifying the possible future climate change in the European and GMR, such as the EU Projects PRUDENCE (Christensen and Christensen, 2007) and ENSEMBLES (Hewitt and Griggs 2004). Furthermore coordinated studies have analyzed the climate change signal in the GMR projected by both regional and global models (Giorgi and Lionello, 2008). In the same time Marcos and Tsimplis (2008) used the CMIP3 (Coupled Model Intercomparison Project) Global Circulation Models (GCMs) (see Table 5.5) to estimate the uncertainty range of the projections in the 21st century of the Mediterranean temperature, salinity and sea level change and they have shown that the GCMs, due to their low spatial resolution, are not able to simulate a realistic Mediterranean Sea in present climate and that their climate projections over the Mediterranean area should be considered with caution.

Beijing Climate Center	China	BCC-CM1
Bjerknes Centre for Climate Research	Norway	BCCR-BCM2.0
National Center for Atmospheric Research	USA	CCSM3
Canadian Centre for Climate Modelling & Analysis	Canada	CGCM3.1(T47)
Canadian Centre for Climate Modelling & Analysis	Canada	CGCM3.1(T63)
Météo-France / Centre National de Recherches Météorologiques	France	CNRM-CM3
CSIRO Atmospheric Research	Australia	CSIRO-Mk3.0
CSIRO Atmospheric Research	Australia	CSIRO-Mk3.5
Max Planck Institute for Meteorology	Germany	ECHAM5/MPI-OM
Meteorological Institute of the University of Bonn, Meteorological Research Institute of KMA, and Model and Data group.	Germany / Korea	ECHO-G
LASG / Institute of Atmospheric Physics	China	FGOALS-g1.0
US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory	USA	GFDL-CM2.0
US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory	USA	GFDL-CM2.1
NASA / Goddard Institute for Space Studies	USA	GISS-AOM
NASA / Goddard Institute for Space Studies	USA	GISS-EH
NASA / Goddard Institute for Space Studies	USA	GISS-ER
Instituto Nazionale di Geofisica e Vulcanologia	Italy	INGV-SXG
Institute for Numerical Mathematics	Russia	INM-CM3.0
Institut Pierre Simon Laplace	France	IPSL-CM4
Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC)	Japan	MIROC3.2(hires)
Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC)	Japan	MIROC3.2(medres)
Meteorological Research Institute	Japan	MRI-CGCM2.3.2
National Center for Atmospheric Research	USA	PCM
Hadley Centre for Climate Prediction and Research / Met Office	UK	UKMO-HadCM3
Hadley Centre for Climate Prediction and Research / Met Office	UK	UKMO-HadGEM1

Table 5.5: CMIP3 Climate Models list (last updated 17 July 2007) (from http://cmip-pcmdi.llnl.gov/cmip3_overview.html?submenuheader=1).

Same results were found from Mariotti et al. (2008) using CMIP3 GCMs for analyzing the uncertainty in the change of the water budget components over the Mediterranean Sea. Furthermore, Sanchez-Gomez et al. (2009) used the ENSEMBLES Atmosphere-only Regional Climate Models (RCMs) (25 km resolution over the Mediterranean Sea, IPCC SRES A1B scenario) to estimate the change of the water budget components and found that the models used (GCMs and RCMs) agree on the drying of the GMR mainly after 2050.

All these previous modelling data were not specifically dedicated to the climate change and its impacts over GMR. Only the recent EU project **CIRCE - Climate Change and Impact Research: the Mediterranean Environment** has been run aimed at predicting and quantifying physical impacts of climate change in the GMR by developing an integrated approach to understand combined effects of climate change. In CIRCE a set of coupled models have been developed with the aim of producing regional climate change projections for the GMR. These projections allow assessing the response of the Mediterranean Sea to climate change over the 1950-2050 period (under the A1B scenario) and the associated uncertainty. All of these CIRCE models include a realistic representation of the Mediterranean Sea, being implemented with a high-resolution numerical model of the circulation of the basin. They have been integrated to produce multi-model ensemble simulations of the present climate and future change projections for the next half a century.

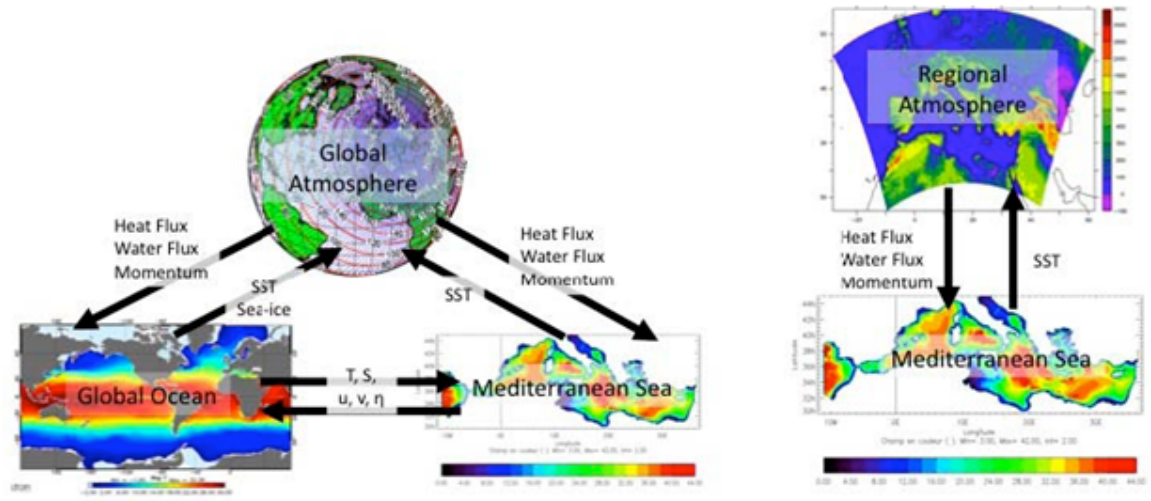

Figure 5.4: Scheme of the basic characteristics of the CIRCE models. *Left*: models set-up with a high-resolution Mediterranean Sea component coupled with a global ocean and a global atmosphere (INGV, IPSL and METEOFrance models). *Right*: models set up with the high resolution Mediterranean Sea component coupled with a high-resolution limited area atmospheric model (ENEA, IPSLReg and MPI models) (source: RACCM - CIRCE EU Project, 2011).

The CIRCE climate projections produced with these models set up (see Figure 5.4) account for the regional-scale processes that characterize the Mediterranean basin and they will provide, for the first time, the possibility to accurately assess the role and feedbacks of the Mediterranean Sea in the global climate system. Table 5.6 shows the main characteristics of the CIRCE models in terms of components and resolution. The simulations that have been conducted during CIRCE project cover two time periods: the second part of the 20th century (1951-2000) and the first part of the 21st century (2001-2050).

	Model	Atmospheric component	Global Oceanic component	Mediterranean Sea
CIRCE GLOBAL MODELS	CMCC-Med (INGV)	**ECHAM** T159 (~80Km), 31 vertical levels	**OPA8.2** ~ 2°x2° (0.5° equator), 31 vert. levels	**MFS(OPA9)** 1/16° (~ 7Km), 71 vertical levels
	IPSL-Glob (IPSL)	**LMDZ global + LMDZ regional** 300 Km, 19 vert. levels + regional Euro-Mediterranean 30 Km, 19 vert. levels	**OPA9** ~ 2°x2° (0.5° equator); 31 vert. levels	**MED8 (OPA9)** 1/8° (9-12 km), 43 vertical levels
	Météo-France (CNRM)	**ARPEGE-Climate TL159c2.5**, 31 vert. lev. (stretched model: 50x50 km over Europe-Mediterranean-North Africa)	**OPA9** ~ 2°x2° (0.5° equator), 31 vert. levels	**MED8 (OPA9)** 1/8° (9-12 km), 43 vertical levels
CIRCE REGIONAL MODELS	PROTEUS (ENEA)	**REG-CM3** 30 Km, 19 vertical levels	/	**MIT-gcm** 1/8° (9-12 km), 42 vertical levels
	IPSL-Reg (IPSL)	**LMDZ regional** 30 Km, 19 vert. levels	/	**MED8 (OPA9)** 1/8° (9-12 km), 43 vertical levels
	MPI-Med (MPI-HH)	**REMO** 25 Km, 31 vertical levels	/	**MPI-OM** 10Km, 30 levels

Table 5.6: Main characteristics of the CIRCE models in terms of model components and resolution (source: RACCM - CIRCE EU Project, 2011).

At the present time the CIRCE model results are quite unique for their outcomes at very high resolution not only for the basic climate and marine variables (air temperature, precipitation, marine temperature and salinity) but specifically for the first regional high resolution projection of sea level for the Mediterranean sea and for the detailed study of the climate extremes such as: temperature and precipitation extremes, cyclones and wind storms, cut-off lows, droughts, extreme ocean wave Conditions and extreme sea levels.

Now CIRCE project is concluded and in few months the **CIRCE EU Project "*Regional Assessment on Climate Change in the Mediterranean*" (RACCM)** will be published. We strongly suggest the usage of all these CIRCE output data for development of specific climatic indicators for the GMR.

5.4 Proposal for new indicators for the Greater Mediterranean Region

We consider important to enhance the usage over the GMR of **indicators of vulnerability**, **vulnerability indices** and **adaptive capacity indicators**.

Indicators of vulnerability and vulnerability indices

The vulnerability indicators are observable variables that indicate the possible future harm can affect a system (or entity). This implies the need to define the system and its troubles before trying to measure the harm by indicators. *"Vulnerability indicators are only appropriate for the purpose of identifying vulnerable people, regions or sectors at local scales when systems can be narrowly defined and hence deductive arguments are available for selecting indicating variables and inductive ones for aggregating them. For other purposes such as … raising awareness, allocating global adaptation funds, monitoring adaptation policy and conducting scientific research, either vulnerability is not the adequate concept or vulnerability indicators are not the adequate methodology." (Hinkel, 2010).*

For the development of vulnerability studies the usage over the northern GMR of the EEA core set of indicators, which include indicators representing different categories, could be useful, despite the many differences in geographical coverage and in the applied methodologies. On the other hand the southern GMR presents a lack of these indicators.

Furthermore, **vulnerability indices** have been developed during the last decades due to the difficulties in collecting detailed data at local and regional scale. These indices are merging different impacts/climate hazards into one aggregated index by using weighting factors for the different hazards and for the various economic factors. These aggregated vulnerability indices are dependent on normative choices regarding the aggregation of monetary, human health and other nonmarket impacts of climate change; of future and current risks; of more likely or less likely impacts; and beneficial and adverse impacts occurring in different sectors and/or regions.

Coastal Vulnerability Indices (CVIs) can be applied to coastal areas in the Mediterranean sea following the same traditional approach by Gornitz et al. (1991) used to identify areas that are at risk of erosion and/or temporary or permanent extreme climatic events (storms, floods, etc): a basic coastal database needs to be created by collecting data such as local subsidence trend, mean elevation, geomorphology classifications, geology classifications, mean shoreline displacement, maximum wave height and mean tidal range.

The CVIs can include four different classes using three percentages as a limit (25%, 50% and 75%) in order to identify the different coastal stretches taking into account the relative vulnerability, the Iglesias-Campos et al. (2010) quoted the case study of Ojeda-Zújar et al. (2009) applied to the Andalusia (Spain) coast. In this case study the CVI had values in between 2, 23 and 35, 35 and the variables were geomorphology, erosion potential, topography, sea level, wave systems and tidal range, which have been classified by a risk level (very low, low, moderate, high and very high), resulting in the CVI as low, moderate, high and very high (see Figure 5.5).

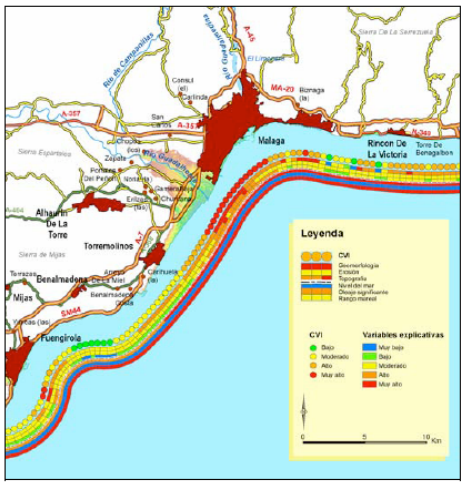

Figure 5.5: Coastal Vulnerability Index applied to the coast of Andalusia (Spain) (source: Iglesias-Campos et al., *2010*).

The development of these CVIs implies a correct assessment of coastal vulnerability on the basis of models and mapping tools. It is essential to assess the various models available and their suitability to provide assessments in line with policy requirements, and for the development of vulnerability indicators easy to be communicated to policy makers.

The CVIs could be applied to the Mediterranean coastal areas in order to assess the coastal cities and ecosystems vulnerability using the observational data and model scenario data available such as sea-level rise scenarios from recent EU project CIRCE, extreme waves situations from National Meteorological Institutes and data on reference layers of geomorphology and erosion from Eurosion (2004).

The **coastal models** are an essential part needed to evaluate coastal vulnerability at different scales. Table 5.7 shows a list of relevant coastal models for the European area and not specifically for the whole GMR (Iglesias-Campos, 2010). All these models require accurate and well geographically distributed datasets and their results depend on the quality of the input data, which will also ensure the comparability of different model outputs for coastal areas in the GMR.

Model	Scale and Spatial Resolution	Temporal Resolution	Input	Output	Impact of drivers	Drivers of change	Examples executed & possible applications	Costs of model use
Inundation Model	- Local – Global - Define by the user and the inputs	Defined by the user	DEM, Sea-level Rise, Scenarios, Socioeconomic data	Maps of potential Flooding	Inundation	Relative sea-level rise	- Global and U.S. Coastal Areas - Coastal areas, RBD in Europe and Neighbouring countries	Low
SLAMM	- Local and Regional (Mx. 100.000 km2) - 1 – 100m	Time-steps of 5-25 years can be used based on the sea-level rise scenario	DEM (i.e. SRTM or LIDAR), land cover, human infrastructures	Map of flooding risk potential for ecosystem	Wetlands change (Erosion, Overwash, Saturation, Salinity)	Sea-level Rise	- US Coast, San Francisco Delaware, Galveston Bay -Coastal areas, bays, estuaries, deltas	Low – Medium
BTELSS	-Local and Regional (Mx. 100.000 km2) - 1km2	Variable time-steps (12s to daily), simulation time up to 100yrs	DEM (+Bathymetry), Climatic data, river discharges, sediment loads, land cover among other datasets. Map habitats	Maps of land change, flooded and eroded areas. Including other maps of indexes such as salinity, sediment balances, etc.	Wetland change	Relative sea-level rise, droughts, rivers discharge	-Barataria and Terrebonne basins, Louisiana, Mexican wetlands -River Basin Districts, Coastal and Transitional Waters, Coastal wetlands, Coastal areas, etc.	High
SimCLIM	Local to global	Varies depending on inputs parameters	DEM, Climate data, sea-level changes, scenarios, impact models.	Maps of flooding potential in coastal areas and ecosystems.	Inundation (i.e. erosion)	Relative sea-level rise, climate change	- Micronesia, Cook Islands, South East Australia - Concrete coastal area, cities, RBDs, regions, countries, regional seas, Europe and neighbouring countries.	Low – High (depending on expertise required)
DIVA	- National to global. Coastline segments.	100 years (5 years time/step).	DEM (SRTM), coastal geomorphology, coastal population and GDP, land use and administrative boundaries.	Estimation of population under flood risk, wetland changes, damages and cost, amongst other outputs.	Coastal and river flooding, coastal erosion, wetland change, salinity intrusion into rivers	Global or regional sea-level rise, population growth, GDP growth, land use-change	- Indonesia, Europe, Southeast Asia - Countries, Regional Seas, Europe and neighbouring countries.	Medium (depending on expertise required)
FUND	- Regional to Global - Defined by the user	From 1950 to 2.300 with time-steps of a year	Population and scenarios on emissions, climate, sea-level and other impacts.	Rates and statistics for decision making	Wetland loss, dry land loss, water impact	Climate Change (and scenarios), Global Warming	Europe	Medium
DELFT3D MODELLING SUITE	- From local to global -Defined by the user	From 1000 to 1000 years	Bathymetry (depth values for all grid points), grid, DTM, roughness, vegetation, wind, pressure, time series (current, water level, etc.)	Maps, graphs and tables regarding water levels, including ground water, water depths, velocities, currents, sediments, etc	Coastal and river flooding, drought, coastal erosion, environmental change, etc.	Wind, waves, storm surges, tsunami, currents, sediments.	Climate change studies, vulnerability and risk assessments, integrated coastal zone management, coastal engineering, EIA, environmental protection, flood risk management, flood forecasting, intake and outfall systems	Medium

Source: Adapted from McLeod *et al.*, 2010

Table 5.7: Summary of the relevant coastal models (source: Iglesias-Campos, 2010).

Adaptation indicators

Other potential indicators to be used consistently in the GMR could be the adaptation indicators, which are particularly needed to mainstream adaptation within and between sectors, to compare adaptation achievements across sectors, regions and countries and to motivate, target and monitor funding for adaptation.

These adaptation indicators can be classified into two main groups:

1. "process based" adaptation indicators,
2. "outcome based" adaptation indicators.

Process-based indicators aim at the monitoring of the development of policies and measures, while outcome-based indicators aim at measuring the effectiveness of actions (see Figure 5.6). Over the next decades the process-based indicators are likely to be relevant in the short term, with outcome-based indicators likely to be important in the longer term due to the fact that only recently adaptation has become a political significant issues for many countries and that the main impacts of climate change can be seen over long time periods. The outcome based adaptation indicators can be affected by: (i) scientific uncertainties, due to the difficulty to know the future climate based on the climate scenarios or climate predictions and (ii) policy uncertainties, due to the incomplete knowledge of adaptive capacity of many countries (such as those in the southern GMR) and their future socio-economic contexts.

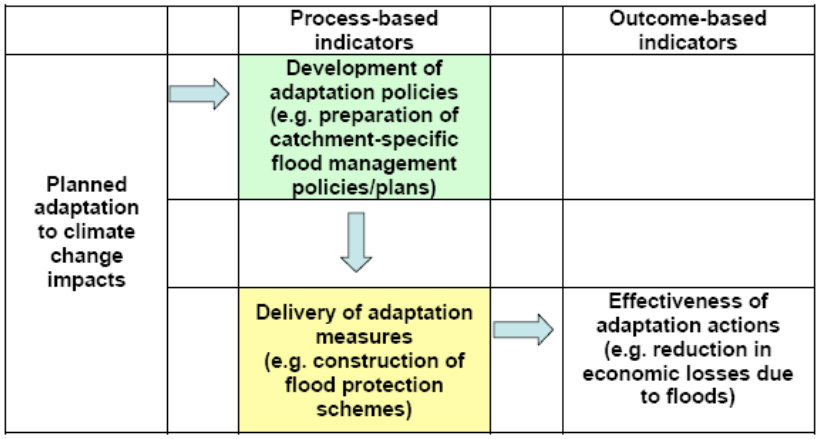

Figure 5.6: Conceptual framework for adaptation indicators (source: Harley and van Minnen, 2010).

5.5 Recommendations

The following are key recommendations for enhancing the indicator-based studies over the GMR:

- **Enhance the data rescue of old climate and marine data in countries of GMR, in particular in the southern part;**
- **Use the updated models output specifically produced for the GMR to develop climatic, marine, vulnerability and adaptation indicators for future periods over the GMR;**
- **Keep the strengthening of the hydrological programmes for monitoring water resources aimed to built Long term-hydrological data series including important variables such as surface discharge, evapotranspiration and groundwater storage and flux;**

- **Enhance the abilities of the countries in the GMR to meet GCOS, regional and national requirements for climate observations and information to support decision-making related to climate and its impacts;**
- **Improve domestic coordination between national institutions and agencies to ensure an effective and cost-efficient response to GCOS, national governments and other clients' requirements for climate data and information;**
- **Enhance the National Reports submission from the countries to UNFCCC on the status of their national programmes for systematic observation of the climate system, in accordance with GCOS guidelines;**
- **Enhance the development of vulnerability assessment for coastal areas by using vulnerability indicators and indices;**
- **Apply coastal vulnerability maps and indices to assess policy effectiveness / efficiency;**
- **Need for analysis of adaptation policy measures (e.g., cost-benefit analysis);**
- **Enhance the estimates of economic costs of climate change;**
- **Enhance the usage of adaptation indicators.**

6 PROPOSAL FOR RELEVANT TRAINING PROGRAMME AT NATIONAL AND REGIONAL LEVEL

Human capital is the most important element of technological development, but it is also the most difficult to create. Creation of human capital is a long process that requires consistency of funding and policies over a long time, which is quite complex to obtain. A practical way to circumvent this problem is to insert even in relatively short-term programmes the support of high education as a primary objective. In this way every programme must have a dual objective: (i) sustain higher education programmes and (ii) develop specialized programmes for the transfer of knowledge needed for the effective exploitation of results of the programmes.

The two objectives are complementary because it is very difficult to train experts to operate and maintain the systems produced by the development projects without a basic level of education. On the other hand, the lack of specialized training runs the risk of creating highly abstract knowledge with limited impact on the target countries. Furthermore, high education without the local implementation of adequate projects can also result in a net brain drain, slowing the development process rather than accelerating it.

Thus we can assume that he presence of a long term objective in a short term project (24-36 months) is not a waste, rather it appears a very effective way of enhancing the results of the project itself. Focusing on a long term objective also allows to ensure that at the end of the project there will be trained personnel capable of picking up the specialized training that had been delivered during the project itself.

Exchange Programmes

A balanced approach needs to be developed with several actions that foster exchanges and increase capacity. The Exchange Programmes (Fellowships and Visitors), must be organized in such a way to maximize involvement of the beneficiary countries in the process of selection of institutions and candidates. The programmes must be directed by Joint Steering Committees where representatives of the host countries and beneficiary countries must be present to select the host institutions, universities graduate and post-graduate university programmes and the training candidates. The Joint Committee will match candidates and institutions according to qualifications and projects themes.

The main components of the programme should be:

1. **Fellowship programme** to allow the participation of students to graduate and post-graduates programmes in top universities and learning centres in the region.
2. **Visitor programme** focused on researchers and practitioners' needs to spend a period at a host research institution to collaborate on specific research. Host institutions should receive a fee for the hosting; furthermore, expenditures, salary and moving expenses of the visiting researchers should be covered. Two levels can be envisaged:
    - Junior Scientist level, for young scientist in the early stages of their careers;
    - Senior Scientist level, for experienced and distinguished scientist to foster integration, technology transfer and building of networks.

High Intensity Training programmes (HIT)

Highly specialized knowledge is sometimes needed to empower beneficiaries to use and understand special tools, for instance the usage of a numerical model or of data assimilation techniques. In this case it is useful to organize high intensity, focused and self-contained, training activities devoted to specific technical issues to be performed locally in the beneficiary country, if possible. Such activities should take the form of one-two weeks training aimed at giving an actual capacity to use a specific tool, like a model, in the local context of a specific application. External and local experts should give the training.

Operational Training

Projects for adaptation to climate change often provide operational products (early warning systems, management systems, etc..) that require sophisticated knowledge for their operations. In order to guarantee the full exploitation of the projects it is necessary to train also the technical human resources that will be able to maintain and operate the systems after the end of the projects. In this case, the projects should contain extensive provisions for the job training. External experts should spend extended periods in the target country to train personnel (4-6 months) and projects should include a detailed section dealing with personnel training. Extended visits in administrations and agencies of the host countries to exchange best practices and lessons learned could also be a component of this practical training.

Twinning Initiative

Universities, research centres, policy analysis institutes and administrations should be linked together with a Twinning Initiative to develop joint programmes and foster joint participation in international programmes.

This activity is aimed at institutions rather than individuals and it should be seen as an opportunity to forge institutional and collaborative networks between institutions. The activities should include the development of joint educational programmes, workshops and meetings to develop joint programmes and proposal. Workshops, visits and training should be aimed at improving management and organizational skills and methods.

A Joint Committee including representative from host and beneficiary countries should be set up to select the institutions for the twinning. Furthermore, specific funding should be set up for supporting.

6.1 Recommendations

We recommend the following actions for supporting training activities in the Mediterranean region:

- **Develop an extensive, jointly managed, Fellowship and Exchange programme for the Mediterranean Region.**
- **Recommend that implementation projects contain a strong component of training aimed to make sure that local personnel will be able to maintain and operate the systems after the conclusion of the project.**
- **Develop Twinning Initiatives between institutions to strengthen regional ties and improve management and organizational skills.**

7 FINAL RECOMMENDATIONS

A set of key actions aimed at (i) improving the climate modelling of the Mediterranean area, (ii) supporting the full implementation of regional systematic observation activities and enhancing national capacities for climate monitoring, (iii) enhancing the indicators-based studies over the Greater Mediterranean Region and (iv) supporting training activities in the area is hereby presented and recommended for actual implementation.

For the improvement of climate modelling of the Mediterranean area:

- Implement **coupled atmosphere-ocean models with a high resolution (7-10 Km)** in the Mediterranean basin able to reproduce the small scale processes related to the complex physiography of the region;
- Include **a realistic representation of the various components of the Mediterranean Sea water budget** in climate models: interactive river runoff and discharge, Black Sea outflow;
- Implement a suite of ocean model that will allow the **telescoping zoom of specific coastal areas** under study. A global model of the Mediterranean Sea will provide the boundary condition to a shelf model (1-2 km) resolution that can be coupled to a very high-resolution (of the order of 100m) model of the coastal zone up to the penetration into bays and rivers.
- The regional models of the Mediterranean Sea should be nested in a high-resolution global model (finer than 100 Km) able to provide a **realistic representation of the main modes of large-scale variability**.

For supporting the full implementation of regional systematic observation activities and enhancing national capacities for climate monitoring:

- Establish designated **climate change coordinating units within the countries**, with appropriate operational branches involving relevant responsible authorities, ministries and academic/research institutions, to which technical assistance and capacity-building support shall be given;
- Establish a **web-based regional Information System** that shall contain information on climate change and variability monitoring and research covering the Greater Mediterranean Region;

- Establish a **Mediterranean forum** to facilitate region-wide coordination across all components of climate observing systems;
- Establish a **platform for exchange and sharing of project expertise** within the larger climate observing community;
- Support the establishment of a **potential regional GCOS Lead Centre in the Mediterranean** Basin within an existing institution, to which technical assistance and capacity-building support shall be provided;
- Strengthen and sustain oceanographic climate monitoring in the Mediterranean by supporting **GLOSS, MedGLOSS, MOON, MedGOOS related ongoing developments** and extensions in the Northern African countries;
- Ensure the **coordination of domestic GCOS activities** and provide the interface to the national, regional and international GCOS concerns through nominated GCOS National Focal Points;
- Ensure the **provision of long-term funding** and other resources needed to sustain GCOS stations and related programmes and networks at the national scale, especially in Northern African and East Mediterranean countries;
- Ensure the **free and unrestricted international exchange of climate system observations and related metadata** from GCOS stations and related networks.

For enhancing the indicators-based studies over the Greater Mediterranean Region:

- Enhance the **data rescue of old climate and marine data** in countries of GMR, in particular in the southern part;
- Use the updated models output specifically produced for the GMR to **develop climatic, marine, vulnerability and adaptation indicators** for future periods over the GMR;
- Keep the **strengthening of the hydrological programmes for monitoring water resources** aimed to built long term-hydrological data series including important variables such as surface discharge, evapotranspiration and groundwater storage and flux;
- Enhance the abilities of the countries in the GMR to meet **GCOS, regional and national requirements for climate observations and information** to support decision-making related to climate and its impacts;

- Improve **domestic coordination** between national institutions and agencies to ensure an effective and cost-efficient response to GCOS, national governments and other clients' requirements for climate data and information;
- Enhance the **National Reports submission from the countries to UNFCCC on the status of their national programmes** for systematic observation of the climate system, in accordance with GCOS guidelines;
- Enhance the **development of vulnerability assessment** for coastal areas by using vulnerability indicators and indices;
- Apply **coastal vulnerability maps and indices** to assess policy effectiveness / efficiency;
- Fulfill the need for **analysis of adaptation policy measures** (e.g., cost-benefit analysis);
- Enhance the **estimates of economic costs** of climate change;
- Enhance the **usage of adaptation indicators**.

For supporting training activities over the Mediterranean region:

- Develop an extensive, jointly managed, **Fellowship and Exchange programme** for the Mediterranean Region;
- Recommend that implementation projects contain **a strong component of training** aimed at ensuring that local personnel will be able to maintain and operate the systems after the conclusion of the project;
- Develop **Twinning Initiatives between institutions** to strengthen regional ties and improve management and organizational skills.

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