CLIMATE-INDUCED CHANGES ON THE HYDROLOGY OF MEDITERRANEAN BASINS – A RESEARCH CONCEPT TO REDUCE UNCERTAINTY AND QUANTIFY RISK

Ralf Ludwig[1], Antonino Soddu[2], Rainer Duttmann[3], Nicolas Baghdadi[4], Sihem Benabdallah[5], Roberto Deidda[6], Marino Marrocu[7], Guenter Strunz[8], Frank Wendland[9], Güleda Engin[10], Claudio Paniconi[11], Franz Prettenthaler[12], Isabelle Lajeunesse[13], Samir Afifi[14], Giorgio Cassiani[15], Alberto Bellin[16], Badr Mabrouk[17], Heike Bach[18] and Thomas Ammerl[19]

[1]Ludwig-Maximilians-Universität München, Department of Geography, Luisenstr. 37, 80333 Munich, Germany
[2]AGRIS Sardegna - Agenzia per la Ricerca de la Agricoltura, Italy
[3]Christian-Albrechts-Universitaet zu Kiel, Germany
[4]Centre national du Machinisme Agricole, du Genie Rural, des Eaux et des Forets, France
[5]Centre de Recherche et des Technologies des Eaux, Tunisia
[6]Consorzio Interuniversitario Nazionale per la Fisica delle Atmosfere e delle Idrosfere, Italy
[7]Centro di Ricerca, Sviluppo e Studi Superiori in Sardegna, Italy
[8]Deutsches Zentrum fuer Luft- und Raumfahrt e.V., Germany
[9]Forschungszentrum Juelich GmbH, Germany
[10]Gebze Yuksek Teknoloji Enstitusu, Turkey
[11]Institut National de la Recherche Scientifique, Canada
[12]Joanneum Research Forschungsgesellschaft mbH, Austria
[13]Université d'Angers, France
[14]Islamic University of Gaza, Palestinian-administered areas
[15]Università degli Studi di Padova, Italy
[16]Università degli Studi di Trento, Italy
[17]Zagazig University, Egypt
[18]VISTA Geowissenschaftliche Fernerkundung GmbH, Germany
[19]Bayerische Forschungsallianz gemeinnützige GmbH, Germany

ABSTRACT

The presented project initiative CLIMB ('Climate Induced Changes on the Hydrology of Mediterranean Basins – Reducing Uncertainty and Quantifying Risk') has recently signed a Grant Agreement in EC's 7th Framework Program (FP7-ENV.2009.1.1.5.2). In its 4-year design, starting from January 2010, the collaborative project for specific cooperation actions (SICA) dedicated to international partner countries shall analyze ongoing and future climate-induced changes in hydrological budgets and extremes across the Mediterranean and neighboring regions. This is undertaken in study sites located in Sardinia, Northern Italy, Southern France, Tunisia, Turkey, Egypt and the Palestinian-administered area Gaza. The work plan is targeted to selected river or aquifer catchments, where the consortium will employ a combination of novel field monitoring and remote sensing concepts, data assimilation, integrated hydrologic modeling and socioeconomic factor analyses to reduce existing uncertainties in climate change impact analysis. Advanced climate scenario analysis will be employed and available ensembles of regional climate model simulations will be downscaled. This process will provide the drivers for an ensemble of hydro(-geo)logical models with different degrees of complexity in terms of process description and level of integration. The results of hydrological modeling and socio-economic factor analysis will enable the development of a GIS-based Vulnerability and Risk Assessment Tool. This tool will serve as a platform for the dissemination of project results, including communication with and planning for local and regional stakeholders. An important output of the research in the individual study sites will be the development of a set of recommendations for an improved monitoring and modeling strategy for climate change impact assessment.

CLIMB is forming a cluster of independent projects with WASSERMed from the Environment and CLICO from Socio-Economic Sciences and Humanities Call of FP7 in 2009 (see Fig. 2). The intention of this clustering is to foster scientific synergy and cooperation between the partner projects to achieve improvements in policy outreach on different spatial scales.

KEYWORDS: Climate Change, Mediterranean, CLIMB, hydrological modeling, vulnerability assessment, risk modeling

THE CLIMB MOTIVATION

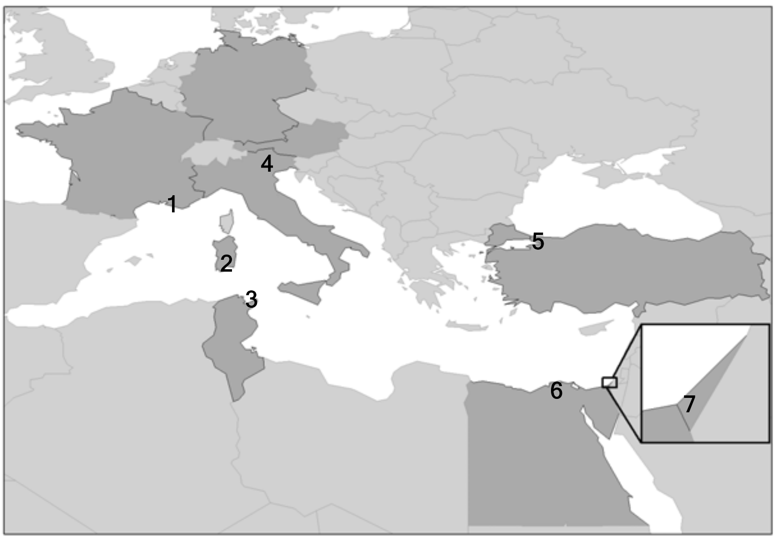
According to current climate projections, Mediterranean countries are at high risk for an even pronounced susceptibility to changes in the hydrological budget and extremes. These changes are expected to have strong impacts on the management of water resources, agricultural productivity and drinking water supply. The regions of the Mediterranean landscape are already experiencing and expecting a broad range of natural and man-made threats to water security. Threats include severe droughts and extreme flooding, salinization of coastal aquifers, degradation of fertile soils and desertification due to poor and unsustainable management practices. It can be foreseen that the changes in the hydrologic cycle will give rise to an increasing potential for tensions and conflict among the political and economic actors in this vulnerable region. There are a number of major obstacles to implementation of adaptation measures designed to achieve sustainable management of water resources. Effective adaptation measures need multi-disciplinary preparation. While there is scientific consensus that climate induced changes on the hydrology of Mediterranean regions are presently occurring and are projected to amplify in the future, little knowledge is available about the quantification of these changes, which is hampered by a lack of suitable and effective hydrological monitoring and modeling systems.

Current projections of future hydrological change, based on regional climate model results and subsequent hydrological modeling schemes, are very uncertain and poorly validated. The conditions required to develop and implement appropriate adaptation strategies are lacking. If adaptation initiatives are proposed at all, they are rarely based on a multi-disciplinary assessment covering both natural and associated social and economic changes.

THE CLIMB OBJECTIVES

With regard to the objectives specified in the ENV. 2009.1.1.5.2-topic [1], modeling capabilities must be improved and appropriate tools developed to advance the capability to assess climate effects on water resources and uses. The project consortium will employ a combination of novel field monitoring concepts, remote sensing techniques, integrated hydrologic modeling and socioeconomic factor analyses to reduce existing uncertainties in climate change impact analysis, and to create an integrated quantitative risk and vulnerability assessment tool. Together, these will provide the necessary information to design appropriate adaptive water resources management instruments and select suitable agricultural practices under climate change conditions. The integrated risk and vulnerability analysis tool will also enable assessment of risks for conflict-inducing actions, e.g. migration. The improved models, new assessment tools, and their results will be evaluated against current methodologies. Improvements will be communicated to stakeholders and decision makers in a transparent, easy-to-understand form, enabling them to utilize the new findings in regional water resource and agricultural management initiatives as well as in the design of mechanisms to reduce potential for conflict. The latter task will be addressed through an interface to the cluster project CLICO, funded under the SSH.2009.4.2.1-topic [2] (see also chapter 3).

An analysis of climate change impacts on available water resources is undertaken in study sites located in Southern France, Sardinia, Tunisia, Northern Italy, Turkey, Egypt and the Palestinian-administered area Gaza. The work plan is targeted to selected mesoscale river or aquifer systems in the above-mentioned partner and SICA countries, representing water management units for regional water authorities (see Fig. 1). Selection criteria included an ex-



1) Thau – 280 km² - Coastal Lagoon - France
2) Rio di San Sperate – 473 km² - Sardinia - Italy
3) Chiba - 286 km² - Cap Bon - Tunisia
4) Noce - 1367 km² – Southern Alps – Italy
5) Izmit Bay – 673 km² - Kocaeli - Turkey
6) Nile – 1000 km² - Nile Delta - Egypt
7) Gaza Aquifer – 365 km² - Gaza – Palest.-admin. areas

FIGURE 1 - The partner countries of CLIMB (+ Canada) and the location of study sites.

pected high susceptibility to climate induced changes in water availability, runoff-regimes, runoff extremes and water quality. The selected sites comprise one to several of the following components, which impose a threat on future water security: high agricultural productivity, irrigation, heavy multi-source nutrient loads and pollution, sea water intrusion or growing water use rivalries.

The site-specific analyses will enable improved assessment and quantification of region-specific vulnerability and risk factors for agricultural, drinking, residential and industrial water. Advanced climate scenario analysis techniques will be employed and dynamical and statistical downscaling of available ensembles of regional climate model simulations will be performed. This process will provide the drivers for an ensemble of hydro(-geo)logical models with different degrees of complexity in terms of process description and level of integration. The outputs of the climate-hydrological modeling chain will deliver estimates of changes in hydrological components, such as timing and frequency of extreme and effective precipitation, run-off, instream mean flow, soil moisture or groundwater balance.

Field monitoring and measurement strategies for surface and subsurface hydrological processes will be tested and adjusted to the specific requirements in the study sites. Synergistic radar and optical remote sensing techniques will be extensively employed to provide steady state parameters (e.g. land-use, land-cover, soil hydraulic properties), to retrieve dynamic model parameters (e.g. soil moisture and roughness, vegetation structures), to monitor process variables (e.g. infiltration, water stress) and to validate model results. Data assimilation procedures will be developed in order to incorporate relevant data and process understanding into existing modeling concepts, thereby significantly reducing uncertainty in predicted hydrological quantities. An important output of the research in the individual study sites will be the development of a set of recommendations for an improved monitoring and modeling strategy for climate change impact assessment. Once the model concepts are optimized to adequately represent the current-state hydrology in the study sites, they will be tested over a range of selected climate change scenarios to project future hydrological budgets and extremes. The integration of hydrological model results and socio-economic factor analysis will enable the development of a GIS-based, modular Vulnerability and Risk Assessment Tool. This tool will serve as a platform to disseminate project results, including communication with and planning for local and regional stakeholders as well as for the discussion and comparison of results with the teams working in the before mentioned cluster.

THE CLIMB STRUCTURE

The project duration of 48 months is necessary and justified due to the difficult data situation in the region, the complexity of methods, the interdependency of work packages (WP) and the necessity to coherently disseminate the results and implications to local and regional stakeholders throughout and, especially, at the end of the project. All efforts in the scientific WPs will be dedicated towards a gradual reduction of uncertainty in assessing climate change impacts on the hydrology of the sites under investigation and shall provide a better basis for achieving water security in southern Europe and the targeted SICA regions.

CLIMB's work plan is divided into eight work packages. In an effort to establish a close link between Theme 6 ('Environment (incl. climate change)') and Theme 8 ('Socio-Economic Sciences and the Humanities') of the programmatic setup of FP7, the funded projects under the Call ENV.2009.1.1.5.2 (WASSERMed & CLIMB) and SSH.2009.4.2.1 (CLICO) are embedded in a cluster of independent EU-projects focused on climate-induced changes in water resources as a threat to security (Fig. 2). Thus, WP 0 is intended to identify and foster the scientific synergies between CLIMB, WASSERMed and CLICO for a more efficient policy outreach.

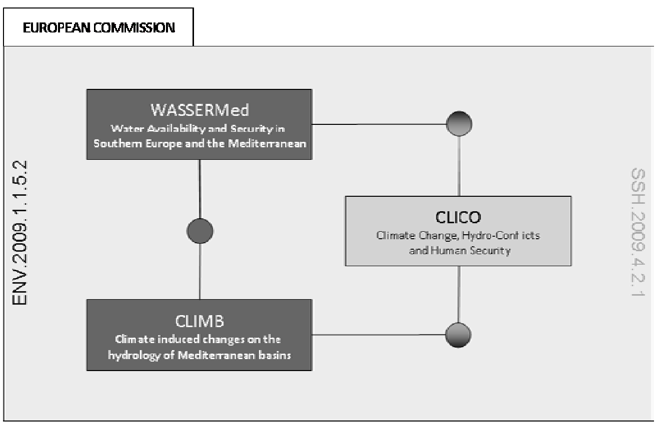


FIGURE 2 - The project cluster of WASSERMed, CLICO and CLIMB.

WP 1 manages and co-ordinates the CLIMB consortium internally. WP 2 is providing and developing the common data infrastructure for and throughout the project. The WPs 3-6 are focused on scientific research, development and innovation of technologies. None of these WPs stands alone, but they are interconnected by means of interfaces, dependencies and feedback loops to ensure an iterative reduction of uncertainty and a more accurate assessment of water-related ecological and economic risk. WP 7 is devoted to the interaction with stakeholders. It builds upon the scientific progress and accounts for a coherent dissemination of project findings. The characterization of the various study sites (WP 3) is the scientific starting point of the project. All activities in WP 3 will be accompanied by intense field campaigns for data collection, conducted by concerted partner actions in each site. WP 3 is sub-divided into three focal areas: i) screening and collecting existing ecological, meteorological, hydrological and socio-economical data (WP 3.1), ii) conducting hydro-geophysical field measurements to gather relevant information for in-depth hydrological process understanding (WP 3.2) and the parameterization of hillslope-scale hydrological models, and iii) to up-scale and regionalize process descriptions using multi-sensorial and multi-scale remote sensing imagery (WP 3.3) and determine spatiotemporal distributions of crucial parameters (e.g. land-use, soil moisture, roughness, infiltration, plant growth) for model applications at the catchment scale (WP 5).

The principle idea behind the structuring of WP 3 and WP 5 is the conviction that the gradual improvement of data availability and accuracy, will consequently lead to improved model parameterizations and, thus, to a reduction of uncertainties in hydrological modeling. Most importantly, the partners complement each other in providing and interfacing surface water and groundwater models of different complexity and level of integration. This will ensure that for each identified climate change related water security issue and site, there will be an ensemble of hydrological models in changing configurations.

This provides the opportunity to combine, compare, and cross-validate a wide methodological range in this field, and will support the reduction of data- and model-prone uncertainties and the identification of the most efficient model complexity given specific boundary conditions and data availability. After calibration and validation of the model ensembles to current climate conditions, they will be run over a range of selected climate change scenarios (elaborated in WP 4) to project hydrological budgets and extremes.

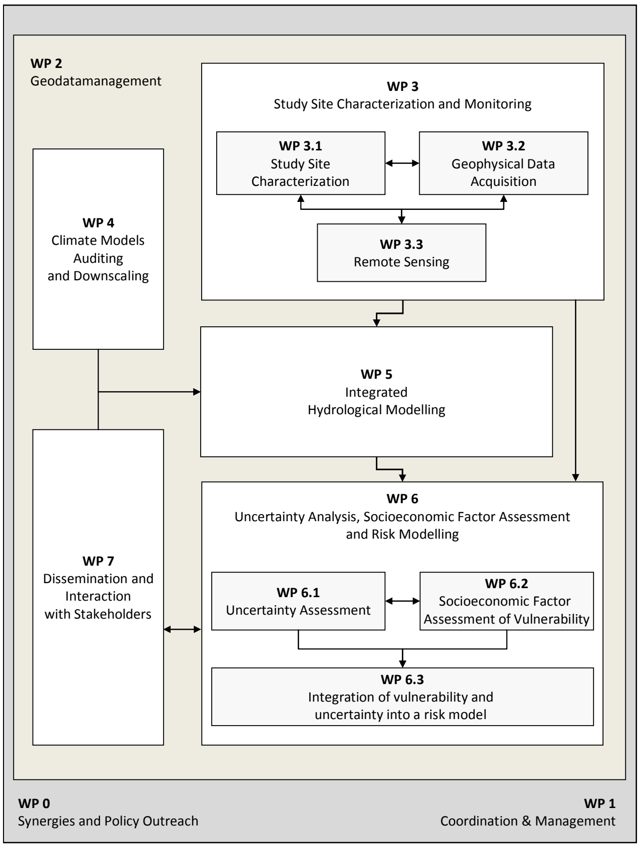


FIGURE 3 - Organizational structure of CLIMB work packages.

TABLE 1 - Hydrological model ensembles in the study sites.

Hydrological Model Ensembles in CLIMB	Large Scale							Small Scale			Applied Model(s) by Partner
	Cap Bon (Tunisia)	Rio Mannu (Sardinia)	Thau (France)	Gaza (Palestinia)	Noce (Italy)	Kocaeli (Turkey)	Nile Delta (Egypt)	Maso Maiano (Italy)	Campidano (Sardinia)		
LMU				X	X		X	X	X		PROMET
CERTE	X		X								SWAT, MODFLOW
CINFAI		X							X		tRIBS
CRS4		X		X							SWAT, CODESA-3D
FZJ				X		X	X				GROWA
GIT						X					MIKE-3
INRS	X	X	X					X	X		CATHY
UA	X		X								SWAT
IUG				X							WMS
UNIPD	X	X			X			X	X		CATHY
UNITN					X			X			GEOTRANSF, FRAC3DVS
UZ							X				FEFLOW
VISTA		X				X					PROMET

In parallel, WP 4 will aim at designing robust procedures allowing auditing (intercomparison and verification) of products coming from different global and regional climate models. These procedures will account for the statistics of average and extreme fields, for water balance conservation in the atmosphere and for problems related to spatial and temporal grid discretizations adopted in the different models. Further, the WP 4 will aim at bridging between the typical scale of climate models and the smaller scale required for hydrological modeling at the catchment scale (WP 5).

WP 6 establishes a comprehensive risk modeling approach for water resource problems under expected climate change in the selected study sites, integrating and quantifying the existing uncertainties (WP 6.1), stemming from insufficient data, inaccurate model descriptions, future climate projections and socio-economic vulnerability factors (WP 6.2). The results of the risk model are used to elaborate recommendations for future water management. The integration of hydrological model results and socio-economic factor analysis will determine the development of a GIS-based, modular *Vulnerability and Risk Assessment Model* (WP 6.3), which shall serve as a platform for the dissemination of project results, and as a communication and planning tool for local and regional stakeholders (WP 7).

EXPECTED CLIMB IMPACT

CLIMB's work plan is targeted towards a substantial advancement of process knowledge and modeling capabilities for a better understanding of the interactions between the biosphere, ecosystems and human activities and thus to better assess climate effects on water resources and uses. The project combines genuine science activities with a strong link to practical application in the targeted regions of the Mediterranean area and thus provides a balance between the three building blocks of environmental research, namely understanding, assessing impact and responding to threats to security in man-environment systems. An increase in general knowledge of water management issues in arid climate, that may be applicable to some EU areas more prone to changes brought about by climate change and/or global warming, can lead to the development of potentially innovative practical and/or theoretical approaches and technologies. It is intended to intensively share and exchange expertise with the Mediterranean Water Scarcity and Drought Working Group of the Mediterranean branch of the EU Water Initiative (MED-EUWI, http://www.euwi.net/ wg/mediterranean). This can be very beneficial to provide supportive guidance for a more concise implementation process for current water-related directives, such as the EU Water Framework Directive 2000/60/EC [3], or the EU-Flood Risk Management Directive 2007/60/EC [4].

The multi-disciplinary setup of CLIMB requires complex and well structured data storage and processing systems. The anticipated GIS-Server system will enable an efficient and standardized use of data gathered by a multinational Consortium, due to the realization of a modern geodata-infrastructure as stated in the EU-INSPIRE directive 2007/2/EC [5]. By using European-wide standards requested therein, this project will presumably be one of the first examples dealing with the cross-border application of INSPIRE for environmental modeling and management. In order to ensure cross-border data exchange by defining new standards and rules for environmental data handling and data transfer, it is obvious why this project has to be based on a European-wide (and beyond) approach.

Taking into account the latest advancements in the field of climate change impacts on the environment, the development of new technologies is focused on the provision of new monitoring systems and modeling tools to significantly reduce uncertainties of climate change impacts on the hydrology in the specified regions. The elaborated climate scenarios and downscaled regional climate model outputs (WP 4) serve as driving inputs for subsequent hydrological models, which transfer the future climate signal into hydrological quantities at the watershed level. The presented project explicitly investigates the varieties of different model response, stemming from a set of 12 internationally renowned hydrological and hydro-geological models, which are applied in changing configurations in the different study sites. This innovative methodological approach will result in a yet unknown possibility to quantify model-prone uncertainty in hydrological predictions. When proven successful, there is reason to expect that CLIMB tools will be internationally recognized and widely adopted by following research activities and operational water resources managers for the development of sound and sustainable adaptation measures to counteract adverse effects of climate change on the natural and human systems.

All activities shall be conducted and evaluated in close co-operation with regional agriculture and water resources experts. This co-operation will serve both to ensure a focus on adaptation measures appropriate for the region and ensure an optimized dissemination of project results. Valid findings will be made available for improved site-specific monitoring and modeling systems for water resources and use assessments under changing climate and land-use conditions. Improvements compared to existing measures will be communicated to stakeholders and decision makers in a transparent, easy-to-understand form, enabling them to utilize the new findings in regional water resource and agricultural management initiatives as well as in the design of mechanisms to reduce potential for conflict. The SICA partners are in charge to substantially contribute to the focused interactions with stakeholders and dissemination activities to establish enduring local and regional stakeholder networks. Potentials impacts of CLIMB may contribute in various ways to:

- foster and intensify the dialogue between scientists, managers, water experts and stakeholders in addressing local impacts of climate changes and identifying means for their assessments

- rise awareness among stakeholders about climate change impacts on water resources and land-uses, which will lead to adequate approaches and adaptation strategies for water resources management and for food security
- empower stakeholders and scientists by providing new tools of decisions making in assessing climate change impacts

These science-management-policy links are indispensable to provide visibility of the research findings beyond the borders of the scientific community, and will allow for an uptake of research results into policy and management practice. The diversity of study sites is expected to foster additional benefits for the development and implementation of adaptation measures, as larger scale stakeholder networks can develop when commonalities in problems and problem prevention can be addressed and mutually discussed through the respective connection to the CLIMB consortium.

ACKNOWLEDGEMENTS

The EC contribution of 3.15 mio € for funding of the CLIMB project under the Grant Agreement no. 244151 is gratefully acknowledged. The CLIMB consortium wishes to thank all contributors and supporters of the CLIMB idea.

REFERENCES

[1] European Commission (2008) FP7 Cooperation Work Programme 2009 - Environment, including climate change (ENV.2009.1.1.5.2). In: C(2008)4598 of 28 August 2008, p.13. Brussels.

[2] European Commission (2008) FP7 Cooperation Work Programme 2009, Socio-Economic Sciences and Humanities (SSH.2009.4.2.1). In: C(2008)4598 of 28 August 2008, p.17. Brussels.

[3] European Commission (2000) Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy (EU – Water Framework Directive).

[4] European Commission (2007) Directive 2007/60/EC of the European Parliament and of the Council on the assessment and management of flood risks (EU – Flood Risk Management Directive).

[5] European Commission (2007) Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE).

Received: December 22, 2009
Accepted: February 02, 2010

CORRESPONDING AUTHOR

Ralf Ludwig
Ludwig-Maximilians-Universität München
Department of Geography
Luisenstr. 37
80333 Munich
GERMANY

E-mail: r.ludwig@lmu.de

FEB/ Vol 19/ No 10a/ 2010 – pages 2379 – 2384