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Editorial

Climate change, water and security in the Mediterranean: Introduction to the special issue

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1. Background and motivation

Climate change is impacting the Mediterranean region in manifold and distinct ways. Observed trends and projections for the future indicate a strong susceptibility to changes in the hydrological regimes, an increasing general shortage of water resources and consequent threats to water availability and management. However, it must be clearly stated that current uncertainties in climate projections and subsequent impact models, a yet incomplete understanding of the impact of a climate change signal on economic mechanisms or the lack of an elaborate and integrated human security conceptual framework are imposing strong limitations on water-related decision-making under conditions of climate change. This is particularly true due to the general lack of regional data and the yet unresolved mismatch of spatial and temporal scales of operation from different scientific perspectives. This Special Issue, composed of sixteen original contributions, illustrates current interdisciplinary approaches to mitigate the existing gaps in the understanding of climate change impacts on water and security in the Mediterranean region. It draws its findings from the research projects CLIMB (*Climate Induced Changes on the Hydrology of Mediterranean Basins*) and WASSERMed (*Water Availability and Security in Southern Europe and the Mediterranean*), both funded under the Seventh Research Framework Program for Research and Technological Development (FP7).

2. The research projects CLIMB and WASSERMed

CLIMB and WASSERMed (both funded under FP7 Theme 6 "Environment including Climate Change") were part of the research cluster CLIWASEC (CLimate change Impacts on Water and SECurity, www.cliwasec.eu). CLIWASEC was built together with the research project CLICO (Climate Change, Hydro conflicts and Human Security; funded under FP7 Theme 8 "Socio-economic Sciences and the Humanities") to build relationships with relevant policy representatives and stakeholders at EU level and Mediterranean and neighboring countries. It tackled most relevant research questions with regard to climate change impacts on water resources as a threat to security in an integrated way.

The CLIMB project analyzed ongoing and future climate induced changes in hydrological budgets and extremes across the Mediterranean and neighboring regions. The work plan was targeted to seven selected Mediterranean river or aquifer catchments, where a combination of novel field monitoring and remote sensing concepts, data assimilation, integrated hydrologic modeling and socioeconomic factor analyses was employed to reduce existing uncertainties in climate change impact analysis. Advanced climate scenario analysis was utilized and available ensembles of regional climate model simulations were audited and downscaled. This process provided the drivers for an ensemble of hydrological 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 were integrated in a Geoportal, serving as a platform for dissemination of project results, including communication and planning for local and regional stakeholders. An important output of the research in the individual study sites is the development of recommendations for an improved monitoring and modeling strategy for climate change impact assessment.

The WASSERMed project followed two distinct streams of research: Mediterranean-wide analysis, focusing on strategic economic sectors, and case studies. It analyzed, in a multi-disciplinary way, ongoing and future climate induced changes in hydrological budgets and extremes in southern Europe, North Africa and the Middle East. It built on existing climate projections in order to assess present and future uncertainties in hydrological budgets in the Mediterranean area, and to provide an

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improved assessment of climate effects on water resources and use sectors. Climatic/hydrologic scenarios served as baselines for impact assessment analysis and risk security analysis of the three targets of the project: (i) the five case studies, (ii) the strategic sectors and (iii) the macro-economic effects. The case studies represented situations, which deserve special attention, due to their relevance to national and human security. Furthermore, impacts on key strategic sectors, such as agriculture and tourism, were considered, as well as macroeconomic implications of water availability in terms of regional income, consumption, investment, trade flows, industrial structure and competitiveness.

3. A summary of results

Besides the different perspectives on climate induced changes as a threat to water security, the CLIWASEC projects were considering different scales at which water related processes can be described explicitly (microscale), mechanistically (mesoscale) or effectively (macroscale). Ambitions, challenges and aims comprised the improved descriptions of scale interfaces. The spatially explicit results of distributed scale-crossing (environmental) models, such as the ones used in CLIMB (micro- to mesoscale) and WASSERMed (meso- to macroscale), can support and feed a yet largely unused interface to socio-economic sciences, which transfer the high-resolution signal of climate induced hydrological change into relevant socio-economic information at the appropriate scale. Understanding the implications of changing water availability in terms of micro and macro economic impacts, adaptation and management options, effects on natural and social systems at large requires the realization of complex interdisciplinary studies. Some papers in this special issue provide neat examples of innovative, eclectic and creative contributions of this type.

It is clear, however, that the current potential to develop appropriate regional adaptation measures towards climate change impacts suffers heavily from large uncertainties. The Mediterranean region is prone to severe observation data scarcity. It was thus a first obligation to establish an improved data base, by means of advanced geophysical field monitoring and multiscale remote sensing, to improve process understanding and to overcome existing limits for robust model parameterization, calibration and validation.

An illustration for the benefit of advanced field monitoring to improve process understanding is provided by Cassiani et al. (2016). The paper identifies the effect of root water uptake and the corresponding subsoil region where active roots are present. It marks the need to consider the effects of different water salinity in the water infiltration process and provided insight about the need to measure quantitatively the plant evapotranspiration in order to close the water balance and separate soil structure effects from water dynamics induced by living plants.

The Special Issue presents several studies employing remote sensing techniques for process monitoring and model data provision. Filion et al. (2016) investigate the potential of radar (ENVISAT ASAR and RADARSAT-2) and LANDSAT data to generate reliable soil moisture maps to support water management and agricultural practice in Mediterranean regions, particularly during dry seasons. Encouraging estimated soil moisture (ESM) maps were obtained for the SAR-based model, showing sensitivity to soil drainage qualities or drainage potential, which can be useful in irrigation management and other agricultural applications. In the paper of Gampe et al. (2016), the Triangle method is applied to estimate actual evapotranspiration (ETR) through the Normalized Difference Vegetation Index (NDVI) and land surface temperature (LST) provided by Landsat TM imagery. Using this information for the parameterization of the physically based, spatially distributed hydrological model WaSiM led to the identification of an increasing drought risk for the area based on the current irrigation procedures. Herrmann et al. (2016) can demonstrate that soil parameters derived from SAR images may replace traditionally used soil maps in regions where soil maps are sparse or missing It is shown that the variance in different GCM–RCMs influences the projected magnitude of future groundwater recharge change significantly more than the variance in the soil parameter distributions derived from conventional and remotely sensed sources. Further, the paper of Herrmann et al. (2016). shows for the period between 1950 and 2100 that overall groundwater recharge will possibly decrease moderately in southern France.

Very interesting findings were obtained from a set of hydrological modeling studies, looking at the robustness of model parameterizations and assessing model uncertainties under the conditions of data scarcity. Meyer et al. (2016) test different deterministic and hybrid geostatistical interpolation methods on newly observed soil textures in the Rio Mannu basin in Sardinia (472.5 km^2) and assess the performance of the applied models. A new soil texture map was calculated from the best prediction model and applied in a spatially explicit and physically based hydrological model. Simulation results show a reduction of all hydrological quantities in future spring seasons, including an earlier onset of dry conditions in the catchment. Sellami et al. (2016) quantify and compare the hydrological response to projections of climate change in two small Mediterranean catchments in southern France and northern Tunisia. Whilst the results in both catchments show consistent trends suggesting that climate change induces alteration in catchment flow regime, the projected magnitudes of alteration as well as its associated uncertainty vary depending on catchment characteristics and flow seasonality. Ehlers et al. (2016) examines the impact of changing climatic conditions on long-term groundwater recharge in the Riu Mannu catchment in southern Sardinia. An extensive sensitivity analysis of the mGROWA model with regard to climate variability, introduction of a regolith zone, soil texture distribution and crop coefficients resulted in an expected decrease of groundwater recharge of 67–82% by the end of the 21st century.

Looking at the major input variable of the hydrological system, Piras et al. (2016) analyze how precipitation extremes propagate into discharge extremes in the Rio Mannu basin. The basin hydrologic response to climate forcings in a reference (1971–2000) and a future (2041–2070) period was simulated through the combined use of a set of global and regional climate models, statistical downscaling techniques, and a process based distributed hydrologic model. Common and contrasting behavior of precipitation and discharge maxima distributions are discussed to better understand how hydrological transformations impact propagation of extremes. It is shown how statistical downscaling algorithms for rainfall can produce more reliable forcing for hydrological models than coarse climate model outputs.

In a climate change impact study, Majone et al. (2016) evaluate climate effects on water resources and hydropower production in the Noce catchment, located in the Italian Alps. Projections indicate an increase in water yield and a transition from a glacionival to nival runoff regime in response to a local increase of the mean temperature and a slight increase of annual precipitation. The changes in water availability reflect in the Technical Hydropower Potential (THP) of the catchment, with larger changes projected for the hydropower plants located at the highest altitudes. Further, the impacts of water use policies, such as the minimum ecological flow (MEF) on THP is analyzed, indicating that in the lower part of the catchment reduction of the hydropower production due to MEF releases from the storage reservoirs counterbalances the benefits associated to the projected increases of inflows as compared to simulations driven only by climate change.

All papers address the issue of how water-sensitive economic sectors could be affected by reduced water availability in the Mediterranean (as predicted by GCM–RCMs), what adaptation alternatives will be available and how they could possibly be implemented. On the other hand, the various investigated topics differ in several dimensions. First, differences exist in terms of regional scale, from the hydrological basin, to the region up to the country. Also, adjustment processes may be driven by specific policy responses, involving water systems and/or economic sectors relying on water resources (e.g., agriculture, tourism),