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Governing and managing water resources under changing hydro-climatic contexts: The case of the upper Rhone basin

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ABSTRACT

Climate change represents a major increase in uncertainty that water managers and policy makers will need to integrate into water resources policy and management. A certain level of uncertainty has always existed in water resources planning, but the speed and intensity of changes in baseline conditions that climate change embodies might require a shift in perspective. This article draws on both the social and physical science results of the EU-FP7 ACQWA project to better understand the challenges and opportunities for adaptation to climate change impacts on the hydrology of the upper Rhone basin in the Canton Valais, Switzerland. It first presents the results of hydro-climatic change projections downscaled to more temporally and spatially-relevant frames of reference for decision makers. Then, it analyses the current policy and legislative framework within which these changes will take place, according to the policy coherence across different water-relevant frameworks as well as the integration and mainstreaming of climate change. It compares the current policy and legislative frameworks for different aspects of water resources management to the projected impacts of climate change on the hydrology of the upper Rhone basin, in order to examine the appropriateness of the current approach for responding to a changing climatic context. Significant uncertainties pose numerous challenges in the governance context. The study draws on adaptive governance principles, to propose policy actions across different scales of governance to better manage baseline variability as well as more 'unpredictable' uncertainty from climate change impacts.

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1. Introduction and background

Shifting climate trends have already been notably observed in mountain zones, while future warming patterns are set to affect mountain regions more acutely, thus leaving their sensitive ecosystems, communities and economies highly exposed to changing climatological and hydrological contexts (Beniston et al., 2011; Gobiet et al., 2014). Effective water governance and management is seen as being at the heart of present and future water challenges, and is considered crucial for building adaptive capacity to be resilient to the impacts of climate change (Nelson et al., 2007). As climate change impacts are increasingly observed, existing challenges within policy and legislative frameworks are being exacerbated by the rate of change within the physical system (Ostrom, 2007). Since policy makers are focusing more and more on climate change adaptation and adaptability (FOEN, 2012), current challenges in the governance context need to be better understood, contextualised in terms of future climate patterns, and finally alleviated.

Scientific efforts have focussed heavily on the reduction of uncertainty through enhanced data collection and modelling (Hawkins and Sutton, 2009; Schneider and Kuntz-Duriseti, 2002). The EU-FP7 ACQWA project aimed to develop climate information downscaled to temporal and spatial scales that are more useful to the challenges decision makers face (Beniston et al., 2011). However, decision makers are increasingly recognising the need to develop better tools to manage and cope with both existing and increasing levels of uncertainty from climate variability and climate change impacts (Hallegatte, 2009). Therefore, the aim of this study is to review and utilise ACQWA results of climate change projections on the hydrology of the upper Rhone basin in order to better contextualise and understand water governance and management challenges that the region will need to address over the next few decades.

After reviewing challenges for the management of uncertainty, we present an overview of the results of the downscaled hydro-climatic change projections. We then draw on the findings of the governance analysis components of ACQWA to assess the current policy and legislative framework within which these changes will take place. Finally we propose actionable governance and management measures that could improve the preparedness of the current system to adapt to projected impacts of climate change in the upper Rhone basin.

1.1. *Preparing for and responding to climate variability and change*

Numerous sources and types of uncertainty exist that affect our ability to both understand and make decisions in the context of climate variability and change. Firstly, it is important to remember that water management and governance has had to develop rules or tools to manage natural climate variability, described by uncertainty ranges (e.g. inter-annual variability of climate leading to sequences or alteration of wet and dry years). This form of 'predictable' uncertainty (Matthews et al., 2011) is generally indicated as stochastic variability or internal climate variability (Deser et al., 2012; Fatichi et al., 2013a).

However, climate change impacts are requiring governance frameworks and management techniques to develop approaches and adapt to more indeterminate, 'unpredictable' uncertainty (Matthews et al., 2011), and potentially irreversible changes in state (reduced run-off contribution from glacier and snow melt, shifts in seasonality, intensification of dry periods). The increasing diversity of future hydro-climatic conditions, or 'non stationarity' (Milly et al., 2008) implies that water governance cannot approach the future based on the assumption that the system will fluctuate within an unchanging envelope of variability.

Not only are the driving forces of climate highly uncertain, but fundamental scientific knowledge gaps limit the reliability of model projections (Hallegatte, 2009) with uncertainties in how climatic and non-climatic pressures will interact on different aspects of hydrology and ecology (Wilby et al., 2010). It is hoped that improved downscaling techniques can remediate some of the scale mismatches between the information provided by climate models and that required by decision makers (Hallegatte, 2009; Maraun et al., 2010). There are also societal sources of uncertainty, not only a result of potential emission pathways, but also how populations will be able to adapt to and cope with the impacts of climate change. Traditional decision making tools and infrastructure have not been developed to take account of the broader levels of uncertainty produced by climate change projections (Hallegatte, 2009). This not only requires modellers to be careful about the communication of their results, but for decision makers and engineers to also rethink their frameworks for potential modifications to water management strategies and infrastructure, as well as moderating their expectations of direct solutions from climate science (Pielke et al., 2012).

It is increasingly recognised that both water governance and management therefore need to include climate variability in everyday operations and longer term decision making as a core component of climate change adaptation strategies (Hallegatte, 2009). An adaptable water management and governance regime therefore would not only need to manage the predictable uncertainty of climate variability (e.g. stochasticity of precipitation) but also the more unpredictable forms of uncertainty arising from climate change impacts. Water governance, the systems and rules in place that affect the use, protection, delivery and development of water resources, therefore needs to be both adaptive and flexible in developing and setting rules that regulate hydro-power, water rights allocations, urban growth and spatial planning for both current climate variability and climate change (Medema et al., 2008). Furthermore, water managers need to be able to make decisions under uncertainty, in their application of rules and the operationalisation of policy for the practical aspects of water allocation and protection, as well as protection from and during extremes (Pahl-Wostl et al., 2009).

1.2. *The upper Rhone basin*

The upper Rhone basin, one of the key case study areas of the ACQWA project in the European Alpine areas, is situated in the Canton Valais (see map in Fig. 1). It represents a surface area of