KLIV Research Report 2013

Climate-land-water changes and integrated water resource management in coastal regions

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KLIV - Climate-land-water changes and integrated water resource management in coastal regions

Aim of the project

KLIV investigates critical questions for sustainable management of water resources, with main geographical focus on coastal regions. KLIV investigation sites include the Swedish Water Management District of Southern Baltic Proper (which in turns includes the Äspö HRL and wider Oskarshamn coastal region related to the National Geosphere Laboratory (NGL) - http://www.geospherelab.se/), with methodological development and comparative catchment studies also carried out for other parts of the world. During 2013, the KLIV research group has further developed and clarified its main research questions, which are investigated across different sites, catchments and regions. These may be formulated as:

1. How does general environmental-climate variability and change interact with water resource changes (in quantity, quality, waterborne nutrient-pollutant loads)?
2. How can and should society identify and detect water resource changes (in water availability/quality, flood/drought risks) in order to appropriately prioritize and respond to them?
3. What governance changes and measures in the landscape can contribute to efficiently control (promote desirable and reduce undesirable) anthropogenic changes to water resources?

Based on answers to these questions KLIV will provide new insights and knowledge on water system change and its possible management.

To arrive at the answers, the KLIV research integrates the inland water system and its adjacent coastal waters, following the water flow and the waterborne transport of tracers, nutrients and pollutants, as well as the climate change effects on these water aspects, along the different water pathways from the respective effect boundaries/entrance zones (land surface for main climate effects, main sources of water, nutrient, pollutant inputs), through the associated hydrological catchments, into coastal waters. Main KLIV working hypotheses are that:

i) This water-following approach will provide new advancements, methods and tools for efficiently detecting-monitoring, modeling-projecting and controlling-reducing undesirable water resource changes.

ii) The results will contribute to efficient achievement of main water-resource and water-related environmental management goals, specifically regarding reduction of water pollution and eutrophication, and adaptation to climate change in coastal regions.

Status of the project

The current KLIV project started in autumn 2012 and extends over a 3-year period (2012-2015). The 2-year post-doc, Andrew Quin, who was recruited to KLIV in December 2012, has during 2013, in addition to the research described below, also been responsible for the development of the KLIV website, www.klivresearch.se with contributions from all KLIV researchers. The website presents the KLIV project, its members and their research and outreach activities.

Main KLIV research activities and results during 2013 are summarized below in terms of the main research questions stated above, with the relevant peer-reviewed publications by KLIV researchers during 2013 listed further below in the Literature section.

Work finalized and published in 2013

1 - Environmental-climate change interactions with water resource change

Key studies related to this research question have addressed the effects of climate change and land-use on hydrological conditions in the landscape, with particular focus on evapotranspiration and stream discharge fluxes (van der Velde et al., 2013), and on erosion intensity and lake sediment geochemistry (Augustsson et al., 2013). Related key studies have also identified historic hyroclimatic shifts that have been driven by human water use for food and energy production (Destouni et al., 2013; Jaramillo et al., 2013).

Furthermore, hydrological and geochemical studies with subsurface water focus have investigated and quantified the variability of water age along hydrological pathways under realistic, transient flow conditions (Safeyeh and Cvetkovic, 2013), and of sulphur isotope ratios in pyrite and dissolved sulphate in granitoid fractures down to 1 km depth, finding evidence for widespread activity of sulphur reducing bacteria (Drake et al., 2013).

2 - Identification-detection of water resource changes

In relation to climate-driven changes of water in the landscape, Bring and Destouni (2013) have developed a methodology for direct comparison of climate model results and actually observed such changes, as basis for prioritizing options and developing strategies for relevant and efficient development of hydrological and water resource monitoring. In this first methodological development and application step, the study used the fast-changing Arctic as its concrete regional application case, precisely because this is a world region with widely recognized unprecedented climate-related change that could be used for creating relatively wide interest in the methodological development and its applicability. With this first development now published, analogous methodological applications and further developments will follow also for other regional case studies, including NGL-related ones.

Furthermore, regarding other methodological developments, in particular for how to meet hydroclimatic variability and change, Jamali et al. (2013) have investigated the question of how to use Geographical Information Systems (GIS) to efficiently locate suitable sites for construction of subsurface dams. With regard to projecting and meeting water quality changes, Cvetkovic (2013) has addressed the key question of how accurate predictive modelling of solute (tracer, pollutant) transport by groundwater may be, in particular regarding the linked key transport processes of advection, macrodispersion and diffusive mass transfer.

3 - Governance and landscape measures for control of water resource changes

In direct relation to and parallel with the above-discussed study by Bring and Destouni (2013), on required monitoring developments for detecting and thereby being able to cope with climate-driven water resource changes in the Arctic, both Azcárate et al. (2013) and Nilsson et al. (2013) have proposed some key development pathways for adaptive environmental and water-food security governance, respectively. Using also here the fast-changing Arctic as a concrete regional case, the methodological development by Azcárate et al. (2013) pointed at the need to identify key knowledge gaps and efficiently bridge them by appropriate use and uncertainty-accounting development of the instrument of Strategic Environmental Assessment linked to hydroclimatic and water resource monitoring (Figure 1). Furthermore, Nilsson et al. (2013) identified a number of concrete indicators that can and should be continuously monitored for appropriate water (and more or less related food) security governance. Also for these developments, now that they have been published for the Arctic as first steps, analogous methodological applications and further developments will follow also for other regional case studies, including NGL-related ones. Additionally, recognizing the key role of urban sustainability, not least for coastal regions with typically large population and urban development pressures, Snickars et al. (2013) have explored urban flows and networks, in particular regarding the sustainability of the Swedish coastal capital, Stockholm.

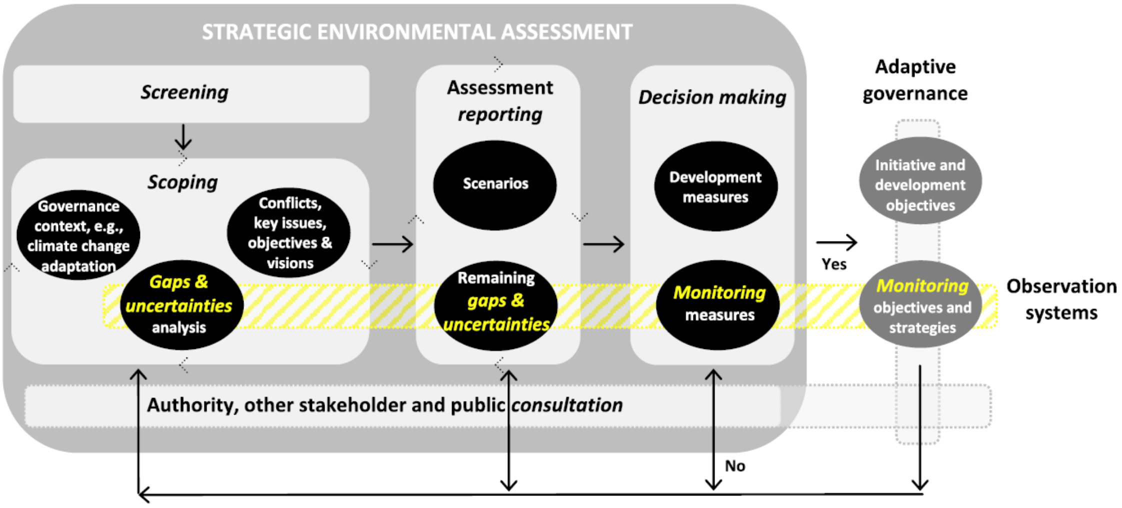

Figure 1: *Adaptive governance framework. The novelty here is the use of Strategic Environmental Assessment to explicitly recognize and handle knowledge gaps and uncertainties, and link environmental monitoring to actual observation systems.*

Ongoing research activities continuing into 2014

1 - Environmental-climate change interactions with water resource change

The whole KLIV group has during 2013 worked on a sub-project for developing a general conceptualization framework for environmental-climate change interactions and change propagation through the whole coupled human-natural system of water on land – this work has been led by Georgia Destouni and is planned to be finalized and submitted for publication in 2014. Water on land is closely linked to human survival and prosperity, and to ecosystem status and development. Urgent needs have been recognized for improved understanding of the changes experienced and propagated by the whole land water system (McDonnell, 2010; Cvetkovic et al., 2012), and of the connections of water changes with planetary boundaries (Rockström et al., 2009) and rapidly changing human systems (Mantonari et al., 2013), including the linked food-energy-water demands of the latter (Howells et al., 2013). In this KLIV work, we have responded to these knowledge needs by synthesizing land water data from different parts of the world and revealing consistent patterns of water quantity and quality changes, which are driven by landscape-internal human-natural water interactions and are propagated by the land water system as a whole toward its boundary interactions with the atmosphere and the sea. We have further developed a conceptualization framework that identifies principal spatiotemporal connections and flow-transport pathways for this change propagation by water through the landscape. This development provides a basis for improved and further developed understanding of water on land as a complex coupled human-natural system, with possible emerging change properties that are not evident from traditional separate study of only individual water components. Research along these lines for the complex life-sustaining system of land water as a whole can thereby lead to novel scientific insights that can improve both water resource and general environmental governance and management.

2 - Identification-detection of water resource changes

In relation to water quality changes, we have during 2013 initiated a new sub-project, led by Anna Augustsson at Linnaeus University, aimed specifically at detecting groundwater quality changes as basis for assessing associated environmental-health risk changes around former glassworks, located throughout Kalmar and Kronoberg counties, Sweden. Assessment of environmental and health risks associated with potential groundwater pollution from such contaminated land sites, and possible necessary remedial action, is time-consuming and costly. It is therefore crucial that such risk assessment, which forms the basis for prioritisation of management interventions, is reliable. Risk assessment, however, typically entails large uncertainties. Thus, identifying and directing efforts towards decreasing critical knowledge gaps, and thereby reducing uncertainty, is important. For people living around contaminated land sites, the overall risk is a function of the total exposure, where multiple paths of exposure generally interact. For metal contaminants originating and leaching from contaminated glassworks sites, one important exposure pathway, which is subject to large uncertainty, is the consumption of drinking water from groundwater wells affected by leached metals. Earlier groundwater analyses have indicated that metals associated with glass production may contaminate local groundwater. The work initiated in this KLIV sub-project focuses on necessary further analyses of metal concentrations in groundwater collected from private wells situated at different distances from former glassworks. Results from this study will provide an important piece of knowledge to the larger puzzle of understanding human exposure to metal contaminants due to living in a Swedish region famous for its glass industry.

3 - Governance and landscape measures for control of water resource changes

We have in 2013 also started a sub-project, led by Andrew Quin and planned to be finalized and submitted for publication in spring 2014, aimed to identify key features of a landscape that may contribute to an essential large-scale ecosystem service: retention of waterborne nutrients and pollutants from various sources. Such a retention service is indeed provided by the landscape - without it, the waterborne nutrient and pollutant loading to downstream inland and coastal waters would be greater and require more, and more costly, abatement measures in order to achieve the same level of protection for downstream waters. This retention service is also closely linked to – and may even be critical for – other types of ecosystem services, such as: clean water provision, nutrient cycling, and recreational water environments - the value of each of these ecosystem-services depends on the large-scale service of nutrient and pollutant retention in the landscape.

In particular, wetlands have been promoted as essential landscape features for the retention of nutrients and pollutants from both point (e.g. wastewater treatment plants and industry) and diffuse (e.g. agriculture, forestry, unconnected wastewater pipes, storm water and atmospheric deposition) sources in the landscape. A number of studies have assessed the local effectiveness of single wetlands in retaining nutrients and thus the reduction in nutrient loads carried by water flow through them. Generally, there is evidence that wetlands can reduce loads locally under favourable conditions. However, what is the corresponding large-scale effect of multiple wetlands distributed throughout the landscape? This question is investigated in the KLIV sub-project.

Our study tackles this question by compiling and analysing available data relevant for assessing effects of wetlands and other landscape features on large-scale nutrient retention. Nutrient retention data has been obtained from the Fifth Baltic Sea Pollutant Load Compilation (PLC5), carried out under the auspices of Sweden's Environmental Emissions Data (SMED). Data on wetlands has been obtained from the Swedish Land Cover Data (SMD) and the Swedish Wetlands Inventory (VMI). The analysis is carried out for the Swedish North and South Baltic River Basin Districts (Figure 2).

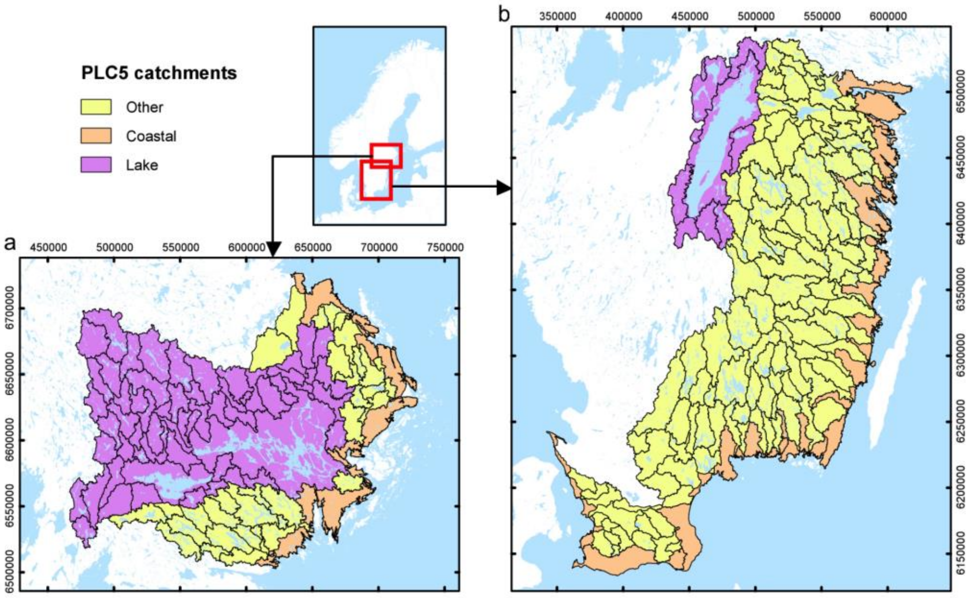

Figure 2. *PLC (sub)catchments for (a) the North Baltic River Basin District (RDB), and (b) the South Baltic RDB. Colors distinguish catchments with flow and nutrient transport pathways that go through a major lake on the way toward the coast (purple), catchments that have have outlets directly at the coast and have been classified as coastal zone catchments by the competent Swedish authority (orange), and other catchments (yellow).*

Already obtained results reveal negligible effect of wetlands on nutrient retention at a landscape-scale, accounting for a wide range of relative wetland areas and, also, the number of wetlands across various sections of the landscape. Instead, the waterborne transport-distance from a catchment to the coast, and the possible existence of large lakes along this transport distance emerge as key features for large-scale nutrient retention in a landscape. These results apply to different types of nutrient sources, including point, agricultural and other diffuse sources, and to both nitrogen and phosphorous transport and retention. For example, Figure 3 shows results for relative retention (nutrient mass retained normalized with total nutrient input mass; with values between zero and one) plotted against the wetland-to-catchment area for total nitrogen (TN, upper panels) and total phosphorus (TP, lower panels), where the wetland-to-catchment area is the ratio of the area of wetlands within a PLC5 catchment to that catchment's total area. These plots show that wetland area has no detectable effect on relative nutrient retention as there is no correlation between relative retention and relative wetland area. The effect of large lakes is seen in the results for catchments with such lakes along the pathways of their flow and nutrient transport to the coast (purple circles, Figure 3), which have larger relative retention than most other catchments. The transport distance effect is indicated by the results for small catchments in the close coastal zone (orange circles, Figure 3), which have smaller relative retention than most other catchments.

Such large-scale results must be considered in environmental management for efficient protection and restoration of good water quality, as well as in assessments and accounts of wetland ecosystem services on landscape scales. In general, such improved understanding of the large-scale nutrient and pollutant retention effects of different features and their distribution in a landscape is needed to better inform decision making aimed at reducing eutrophication and pollution of aquatic ecosystems.

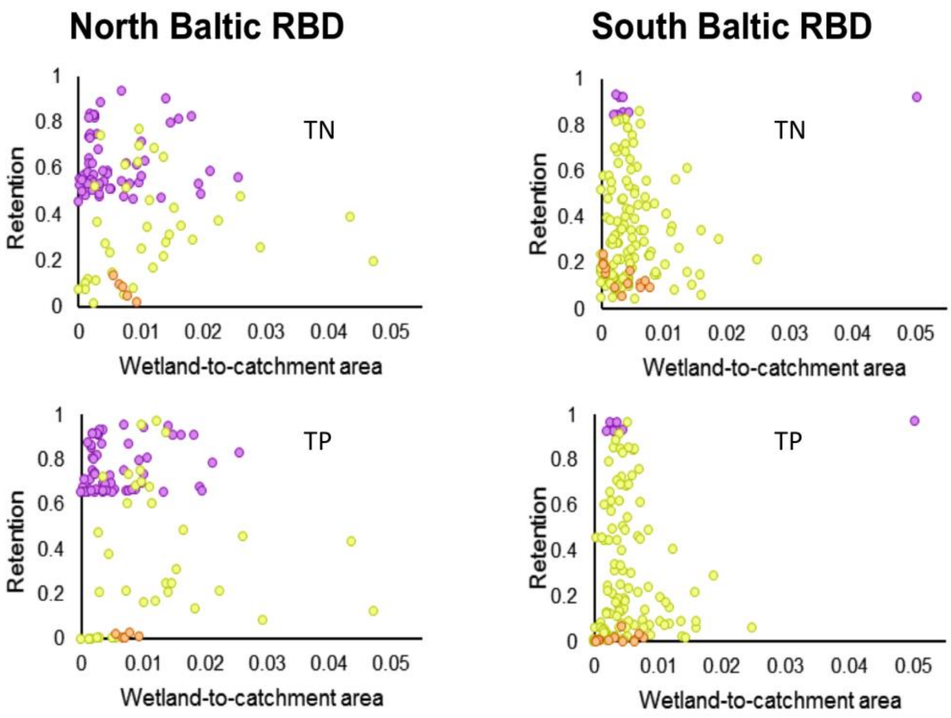

Figure 3. *Relative nutrient retention versus relative wetland area in PLC (sub)catchments (shown in Figure 2) for the (left panels) North Baltic River Basin District (RDB) and (right panels) South Baltic RDB. Symbol colors distinguish results for catchments with flow and nutrient transport pathways that go through a major lake on the way toward the coast (purple circles), catchments that have have outlets directly at the coast and have been classified as coastal zone catchments by the competent Swedish authority (orange circles), and other catchments (yellow circles).*

Spin-off

In 2013, Georgia Destouni (GD) from KLIV together with Stockholm University post-doc Arvid Bring (AB) and NOVA handling officer Anna Rockström have coordinated and arranged the first Annual Science Meeting of the National Geosphere Laboratory (NGL), held 7-8th November, 2013, in Oskarshamn. AB and GD have also during 2013 developed the NGL website at www.geospherelab.se, which provides detailed information about the first annual science meeting and other NGL activities in 2013. In summary, the purpose of this first annual meeting was to build up, support and integrate the NGL research community and the further development of NGL as a national research infrastructure. In addition to GD's coordinating role, other KLIV members have also been actively involved and active in all NGL activities during 2013.

Literature

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(see list below for references to 2013 publications by KLIV researchers)

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