KLIV Research Report 2014

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 a geographical focus on coastal regions. KLIV investigation sites include the Swedish Water Management District of Southern Baltic Proper, which in turn includes the Äspö Hard Rock Laboratory (HRL) and the wider Oskarshamn coastal region related to the National Geosphere Laboratory (NGL). Methodological development and comparative catchment studies are also carried out for other parts of the world. During 2014, the KLIV research group has continued with research into its main research questions. Formulated in last year's report, these are:

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, KLIV research integrates the inland water system and its adjacent coastal waters, following the path of water flow and waterborne transport of tracers, nutrients and pollutants, as well as the climate change effects on these, 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 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

2014 was the final year of the KLIV project, which started in autumn 2012. Some work and publications are due to be completed in 2015; thus, the final report will be submitted next year.

Post-doc Andrew Quin, recruited to KLIV in December 2012, has continued development of the KLIV website during 2014, in addition to carrying out research described further below. The website provides a record of the KLIV project, outlining KLIV's research questions and approach, summarizing KLIV research and outreach activities, and presenting its members.

The main KLIV research activities and results published in 2014 or in-press are summarized below, categorized according to the research questions stated above. Peer-reviewed articles authored by KLIV researchers during 2014 are listed further below in the Literature section.

Work finalized and published or in-press, 2014

1 - Environmental-climate change interactions with water resource change

Local, regional and global studies by KLIV researchers described in this sub-section address the effect of climate change and land-use change on water resources.

Together with other researchers, Georgia Destouni has worked on developing means of identifying primary causes for change in water resources (climatic or anthropogenic) in regions and catchments in Sweden (Van der Velde et al., 2014) and across the globe (Jaramillo & Destouni, *in-press*). Such knowledge can help to inform water management and adaptation strategies and highlight the need to differentiate strategies regionally in order to protect vulnerable ecosystems and water resources. A further regional study has highlighted climate change effects on the often overlooked Baltic Sea coastal environment, including hydrological change (Strandmark et al., *in-press*).

Two studies focussed on the Selenga River, an unregulated basin in Russia and Mongolia, contributing to >60 % of Lake Baikal's inflow (Chalov et al., 2014; Törnqvist et al., 2014). Chalov et al. (2014) investigated the significance of peak flows for sediment loading, erosion/deposition patterns, suspended particulate matter and heavy metal transport. Analysis of field data and hydrological modelling revealed that annual sediment loading and pollution increases by 70-80 % due to peak flows. Also, a long-term, decadal trend of reduced sediment transport was identified, caused by abandonment of cultivated lands and, also, hydroclimatic factors. Törnqvist el al. (2014) assessed the effects of climatic change on the historical and future discharge of the Selenga River. From 1938-2009, with regional temperatures rising nearly twice as fast as global, the intra-annual variability of discharge has decreased – indicating degradation of permafrost in the region. In the future, with increased regional warming, permafrost thaw will bring about further hydrological changes; however, it is difficult to predict changes to run-off due to challenges in hydrological modelling, which failed to reproduce historical behaviour. In-depth studies of such an unregulated basin can help to better understand hydrological processes and inform management decisions in similar basins.

Other research into water resource changes due to changing hydro-climatic conditions has focused on changes to soil moisture (Destouni & Verrot, 2014; Verrot & Destouni, *in-press*). Destouni & Verrot (2014) present a conceptual and analytical framework for linking hydro-climatic change to soil water and groundwater conditions and assessed the long term variability of soil moisture in a Swedish drainage basin, revealing a major increase in the frequency of dry soil events during the last century, suggesting that hydrological and agricultural droughts may become more frequent in the future in spite of an anticipated increase in preciption. Verrot & Destouni (*in-press*) further investigated variability and change in soil moisture focusing on the effects of snow dynamics.

2 - Identification-detection of water resource changes

The sources and processes which control trace metals in groundwater have been studied in two different settings: fractured crystalline rock and a black-shale mining area. The studies in the rock setting include identification and quantification of the mechanisms controlling high Cesium concentrations in groundwater of predominantly marine origin (Mathurin et al. 2014a), and relatively low concentrations but variable fractionation patterns of the rare earth elements in groundwater throughout the upper kilometer of the crust (Mathurin et al. 2014b, Alakangas et al. 2014). The study in the mining area focuses on the controls and leaching potential of Nickel, Uranium and Arsenic in various types of black shale materials, via a long-term humidity cell, sequential chemical extractions and X-ray absorption spectroscopy (Yu et al. 2014).

Further research into chemical and solute transport processes in groundwater has been carried out. Vladimir et al. (2014) present a time-domain random walk aproach for modelling solute transport in three-dimenionsal aquifers. Vladimir & Gotovac (2014) also present a methodological development using a time-domain random-walk approach to modeling chemical transport in fractured rock, which can be used to quantify uncertainty of reactive transport modeling in such media.

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

KLIV researchers have been involved in projects related to: implementation of mitigation measures and management of the environmentally-stressed Baltic Sea; human-health and environmental issues due to chemical elements occuring or being released into water resources; and means of assessing groundwater resources potential in crystalline bedrock terrain.

A number of KLIV studies focused on the management and mitigation of nutrient loading to the Baltic Sea (Andersson et al., 2014; Bring et al., 2015; Quin et al., *in-press*). Andersson et al. (2014) focused on phosphorus loading to the Baltic Sea, showing that catchments with a high degree of eutrophication do not typically export phosphorus to the Baltic Sea. Furthermore, lake catchments with high phosphorus loads from agriculture did not considerably contribute phosphorus to the Baltic Sea due to nutrient retention in lakes. Similarly, Quin et al. (*in-press*) showed that nutrient retention due to wetlands was not statistically detectable at the landscape scale. Instead, catchment retention at the landscape scale is primarily correlated with the transport distance along the flow network from nutrient sources to the Baltic Sea and, also, with the presence of large lakes. To further spread this message, an article summarising this work was published in the Baltic Sea magazine, *Havsutsikt*, aimed at spreading Baltic Sea science to the wider public. Bring et al. (2015) showed how variability in CMIP5 (Coupled Model Intercomparison Project 5) simulations for climate change affected the long-term nutrient reductions for rivers with outlets to the Baltic Sea. Selroos & Destouni (2015) assessed how spatial and temporal variability in flow influences solute transport in catchments. These studies show how management decisions and goals need to take into account spatial and temporal factors which may vary across catchments and/or regions.

A further challenge to effective management concerns institutional development towards enabling better stakeholder participation in local water management. Franzén et al., (2015) analyzed how institutional legacy affected organizational arrangements and stakeholder participation in two adjacent catchments in southern Sweden. Organisational arrangements differed, despite the proximity of the catchments and similar characteristics, and national and regulatory frameworks. Institutional development needs include a means of recognizing and organizing stakeholders, their voluntary involvement and clear leadership.

Regarding human and environmental health effects of exposure to chemical elements, Augustsson & Berger (2014) assessed risks of excess fluoride intake among Swedish children in households with private wells. The study presented a way of improving on typically static, single-source methods assessing exposure by using a probabilistic multi-exposure pathway approach. Also, Amneklev et al. (2015) assessed the question of whether the use of bismuth and silver in cosmetic products should be a source of environmental and, also, resource concern.

In crystalline bedrock terrain it is often difficult to predict the occurrence of typically limited, but potentially useful, groundwater resources. Earon et al (2014) developed a method for assessing groundwater resources potential in such terrain based on geographical and topographical factors. The method, which only requires geological maps, feature maps and topography, is suitable for municipal or regional-level planning.

Ongoing research activities continuing into 2015

1 - Environmental-climate change interactions with water resource change

KLIV's water-following approach, as mentioned in the *Aim of the project*, has been further advanced through the preparation and development of a manuscript from 2013 through to today. Throughout 2014, the manuscript has undergone several stages of refinement, with input from all KLIV members and a number of other researchers at Stockholm University. It has been submitted to the journal *Global Environmental Change*. In this manuscript main author, Georgia

Destouni, argues that traditional conceptualisations of the water cycle display gaps and inconsistencies. To overcome these, a new conceptualization is presented which treats freshwater as a continuous system within the geosphere, and which emphasises often neglected aspects of: i) coastal divergent catchments; ii) zones of freshwater changes (surface, subsurface, coastal, observational); iii) water pathways as system-coupling agents, linking and partitioning change between zones, iv) interactions with the anthroposphere as integral system pathways across zones. The manuscript highlights the implications of paying attention to these aspects; also, changes in large-scale water fluxes and nutrient loads due to human-driven changes are identified. Using this conceptualization as a framework of understanding can be used to help advance science, policy and management of freshwater.

2 - Identification-detection of water resource changes

Research due to be carried out during 2015 includes a study where fluorine sources and mobility will be identified and characterised in a setting with high natural fluorine concentrations in the geological materials, in Laxemar SE Sweden. The study will include soil sampling and analytical work such as sequential chemical extractions and scanning electron microscopy. The aim is to unravel the mechanisms leading to high (harmful/toxic) fluorine concentrations in surface waters.
Another study aims to detect metal leaching from acid sulfate soils via geochemical studies of sediments in recipient estuaries. A long sediment core has been sampled in the Vörå creek estuary, western Finland, and analysed by a variety of chemical and mineralogical techniques. The overall aim is to characterize: (i) the extent of metal leaching from the acidic soils, and (ii) by what mechanisms metals are ultimately removed when the acidic metal-rich waters are neutralized.

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

Following the aforementioned research investigating the landscape-scale role of wetlands for nutrient retention (as described in the previous section), Andrew Quin and Georgia Destouni have continued with investigating an additional ecosystem service often associated with wetlands, namely the regulation of water flow. On a local scale, wetlands can help to regulate water flow – reducing flooding and providing a slow release of stored water during drier periods. Thus the protection, restoration and creation of wetlands are often suggested as a means of mitigating undesirable effects of flow variability. However, similar to the previously described research, it is valuable to investigate and quantify the landscape-scale effect of wetlands on flow regulation relative to other landscape features.

A preliminary analysis has been carried out for 85 catchments (with areas ranging in size from 0.8 km^2 to 15,395 km^2) in both the North and South Water Management Districts (WMDs) in Sweden. Preliminary results show that wetlands play a small role in regulating water flow relative to the role played by other landscape features: catchment size and, also, the area of lakes relative to the catchment size are more strongly correlated with flow regulation. This was assessed by plotting the co-efficient of variation of run-off (standard deviation divided by the mean) against catchment size (Fig. 1) and the area of lakes relative to the catchment size (Fig. 2) for the North and South WMD catchments. However, unlike the previously mentioned research, where the role of wetlands in providing landscape-scale nutrient retention was undetectable, it is interesting to note that wetlands were, here, found to be slightly correlated to flow regulation at the landscape scale (Fig 3).

An initial explanation for this difference in results is due to the different water-following pathways for the two cases. In the case of flow regulation, enough water from source (where precipitation falls on the land surface) to output (at water run-off measurement stations) passes through wetlands for them to have an effect at the landscape scale. On the other hand, in the case of nutrient loading, the proportion of waterborne nutrient loading which passes through wetlands from sources (primarily the agricultural landscape) to output (the river outlet to the sea) is too small for wetlands to have any significant effect at the landscape scale. An additional aspect to take into consideration for both of these cases are the sub-surface flow pathways.

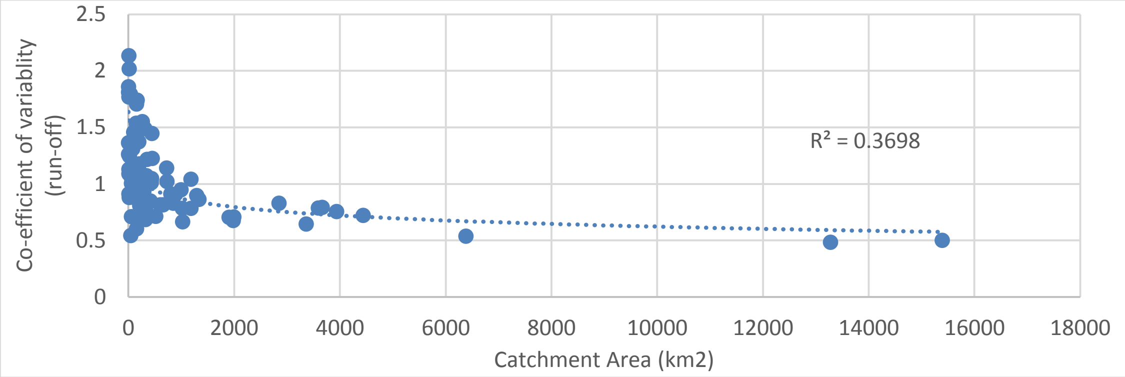

Figure 1: The co-efficient of variability for run-off versus catchment area (km2) for 85 catchments in the North and South WMDs in Sweden

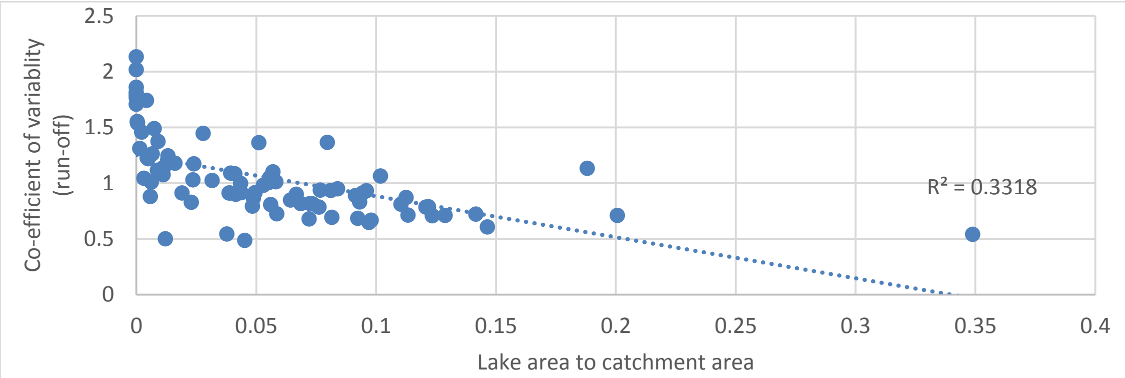

Figure 2: The co-efficient of variability for run-off versus the relative area of lakes within each catchment for 85 catchments in the North and South WMDs in Sweden.

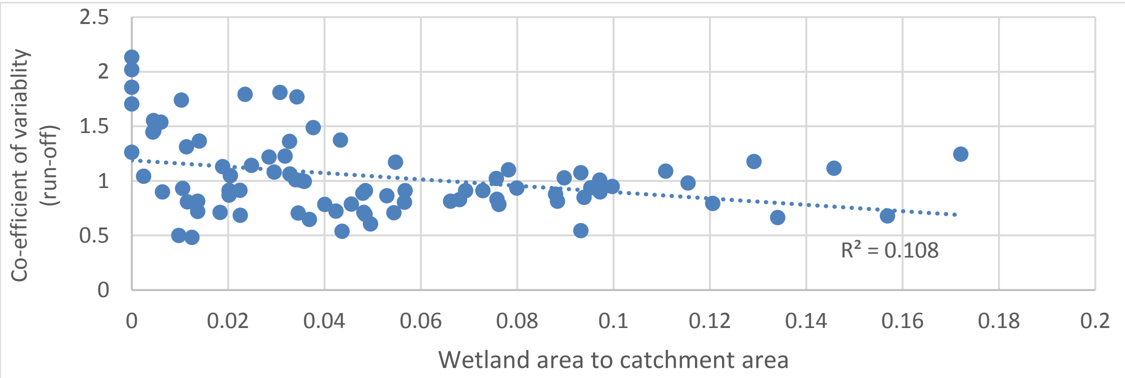

Figure 3: The co-efficient of variability for run-off versus the relative area of wetlands within each catchment for 85 catchments in the North and South WMDs in Sweden.

Spin-off

In 2014, Georgia Destouni from KLIV, together with Zahra Kalantari (post-doc, Stockholm University), Leah Levi (PhD student, Royal Insitute of Technology) and Anna Rockström (Nova handling officer), coordinated and arranged the second Annual Science Meeting of the National Geosphere Laboratory (NGL), held 3-4th November, 2014, in Oskarshamn. The Annual Science Meeting was covered by different media. The first NGL Annual Science

Meeting was held 7-8th November, 2013, as described in the previous year's report. Information about NGL, its activities and the Annual Science Meetings is available at the website, developed by Arvid Bring (post-doc, Stockholm University) and Georgia Destouni. In summary, the purpose of these Annual Science Meetings was to build up, support and integrate the NGL research community and further the development of NGL as a national research infrastructure. In addition to Georgia Destouni's coordinating role, other KLIV members have also been actively involved in NGL activities.

KLIV members, Berit Balfors, Jerker Jarsjö and Andrew Quin, have been involved in the project, ECOPOOL, together with researchers from the hosting institution, Södertörn University, and other research institutions and companies. The overall aim of the project is to contribute to an improved understanding of the feedbacks between ecosystems and society for sustainable governance. Thus, considering KLIVs research aims – especially those regarding governance measures for control of water resource changes, there are clear links to the ECOPOOL project. Research by KLIV members in conjunction with the ECOPOOL project includes identification of key needs for development of institutions to better enable stakeholder participation in local water management (Franzén et al., 2015) and strategies and priorities for managing phosphorus loads to the environment (Andersson et al., 2014).

KLIV member, Anna Augustsson, started work on a project investigating the risks of living near to former glassworks site situated throughout Southeast Sweden. Starting with support from within KLIV, this research has been expanded to become a full NOVA FoU project. Now, Anna Augustsson is project leader for the NOVA FoU project *Exposure to arsenic, lead and cadmium via drinking water consumption near contaminated glassworks sites*.

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