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Multi-decadal lake-level dynamics in north-eastern Germany as derived by a combination of gauging, proxy-data and modelling

Knut Kaiser [a,*], Ingo Heinrich [a], Iris Heine [a], Marco Natkhin [b], Ralf Dannowski [c], Gunnar Lischeid [c], Thomas Schneider [d], Johanna Henkel [d], Mathias Küster [e], Karl-Uwe Heussner [f], Oliver Bens [a], Jana Chmieleski [d]

[a] GFZ German Research Centre for Geosciences, Telegrafenberg, D-14473 Potsdam, Germany
[b] Thünen-Institute of Forest Ecosystems, Alfred-Möller-Strasse 1, D-16225 Eberswalde, Germany
[c] Leibniz Centre for Agricultural Landscape Research (ZALF), Institute of Landscape Hydrology, Eberswalder Strasse 84, D-15374 Müncheberg, Germany
[d] Eberswalde University for Sustainable Development, Faculty of Landscape Management and Nature Conservation, Schicklerstrasse 5, D-16225 Eberswalde, Germany
[e] University of Greifswald, Institute of Geography and Geology, Friedrich-Ludwig-Jahn Strasse 16, D-17487 Greifswald, Germany
[f] German Archaeological Institute (DAI), Im Dol 2-6, D-14195 Berlin, Germany

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SUMMARY

In the glacially formed landscape of north-eastern Germany pronounced hydrological changes have been detected in recent decades, leading to the general question how lake levels and related groundwater levels perform in a long-term perspective, i.e. during the last c. 100 years. But long-term lake-level records are rare; most observations do not start before the late 20th century. Therefore, the potential of historic hydrological data, comprising drowned trees (as a geo-/bioarchive) and aerial as well as map imagery (as a document archive) was tested in order to derive discrete-time lake-level stands. These data are contrasted with lake-level simulations, obtaining a continuous-time series.

Two small glacial lakes without connection to the stream network (i.e. closed lakes) were investigated in the Schorfheide area, c. 70 km north of Berlin. Both are dominantly fed by groundwater and precipitation but differ in their hydrogeological and catchment characteristics. For one lake a c. 40 year-long gauging record is available, showing high lake levels in the 1980s followed by a lowering of c. 3 m till the mid-2000s. In both lakes submerged *in situ* tree remains were discovered and dated by dendrochronology, revealing low lake levels during the first half of the 20th century. One lake was almost completely dry until c. 1960. Aerial photos provided data on lake levels since the 1930s which are corroborated by evidence of topographic mapping. Combining the empiric data with retrograde lake-level modelling, a well-proven lake-level record can be established for one lake that covers the last c. 90 years. The same general lake-level dynamics could be reconstructed by means of proxy data for the other lake. In both cases climate has been the dominant driver of lake-level dynamics. Comparisons with other multi-decadal lake-level records from the region show that these differ, depending on the hydrological lake type which modifies water feeding and water level. The results clearly showed that lake levels exhibited substantial long-term changes that should be taken into account in future hydroclimatic and hydrological studies.

1. Introduction

Despite the relatively early commencement of hydrological records in central Europe, monitoring data are often heavily constrained by the length of the observation period. While some gauging stations at large rivers and lakes as well as tidal gauges along the North and Baltic Sea coasts have operated since the 18th and 19th century (e.g. River Elbe/Magdeburg: 1727, River Rhine/Cologne: c. 1770, River Oder/Frankfurt O.: 1810, Lake Constance: 1816, Lake Müritz: 1879; Strigel et al., 2010; www.undine.bafg.de), gauging of low-order streams and lakes as well as aquifers and peatlands were established very late, i.e. mostly from the last third of the 20th century onwards. Furthermore, most hydrological monitoring sites are located along drainage networks and are thus heavily influenced by discharge regulation and other human impacts (e.g. hydromorphological change, intensive land use). These sites are less suitable for the tracing of long-term hydrological changes driven by climatic impact compared to pristine catch-

* Corresponding author. Tel.: +49 3312882830; fax: +49 3312881002.
E-mail address: kaiserk@gfz-potsdam.de (K. Kaiser).

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ments. While the empirical detection of hydrological changes is an indispensable prerequisite for environmental and climate impact research, the general challenge to develop long time series at suitable sites still remains. Long records generally help to identify trends and to separate short-term (i.e. high frequency) from long-term (i.e. low frequency) dynamics. This in turn is important for the attribution of the changes detected (Merz et al., 2012). Not all hydrological phenomena observed in a relatively short period can be unequivocally attributed to global (i.e. climate and land use) change. Some changes may even reflect periodic long-term natural processes (Blöschl and Montanari, 2010), basically driven by natural solar and atmospheric dynamics.

For the extension of hydrological time series into the past, a comprehensive bundle of well-developed historic-hydrological and palaeohydrological methods is required (e.g. Brown, 2002; Benito and Thorndycraft, 2005; Brázdil et al., 2006; Gregory et al., 2006; Meko, 2006; Baker, 2008). This historical or reconstructive perspective on (landscape) hydrology forms a research field usually established in geosciences/geography and palaeoecology including dendrohydrology. But even in central Europe, with its advanced hydrological, climatic and ecologic monitoring systems, a close linkage between observation data on the one hand and reconstruction data on the other is still rarely found (e.g. Schönfelder and Steinberg, 2004; Brázdil et al., 2005; Dressler et al., 2007; Hilt et al., 2008; Czymzik et al., 2010; Kämpf et al., 2012).

In this paper we present a case study on the nexus of observation and reconstruction from north-eastern Germany, where

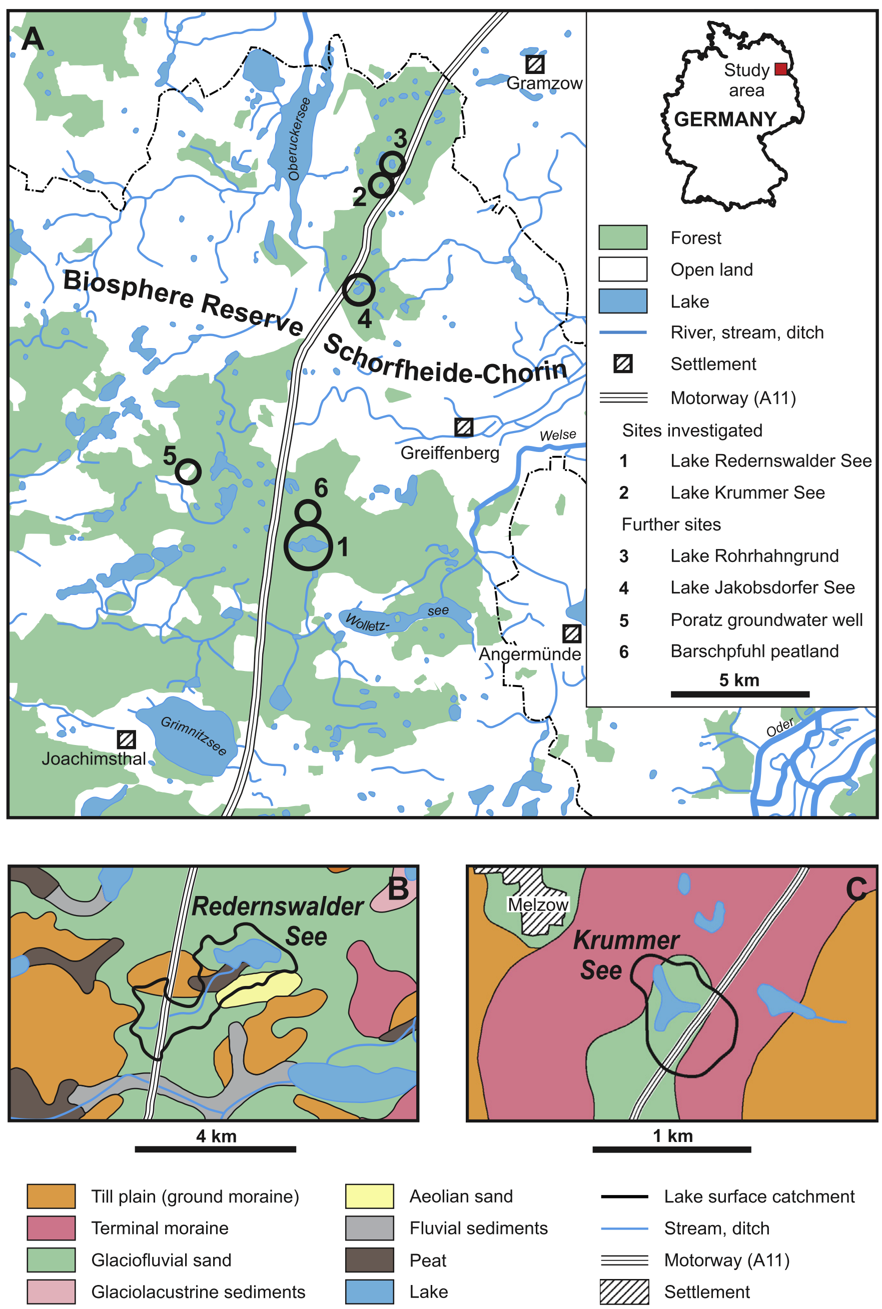

Fig. 1. Sketch maps with the sites investigated. A – Overview on the study area with the main sites investigated and with further sites used for comparison. B – Drainage network and geology in the surroundings of Lake Redernswalder See (after LGRB, 1997, modified). C – Drainage network and geology in the surroundings of Lake Krummer See (after LGRB, 1997, modified).