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Editorial

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Paleohydrological data, sometimes called "proxy records," reveal features of hydrologic variability not amenable to study with short instrumental hydrologic time series. Included are low-frequency features at wavelengths longer than the instrumental record, as well as high-frequency features that might differ in statistical properties from those that happen to be sampled by the instrumental record. Advances in paleohydrological methods and the expanded field collections of paleohydrologic proxies worldwide enable the reconstruction of different components of the hydrologic cycle on various scales of time and space. Reducing uncertainty about the variability of hydrologic processes is a major goal of paleohydrologic studies. New methods and datasets will help achieve this goal. At the same time, it is important to assess and appreciate the strengths and weaknesses of the expanding network of available proxy records.

This special issue, "Advances in Paleohydrology Research and Applications," presents a set of papers selected to illustrate research at the frontiers of paleohydrology. The solicitation for the special issue targeted papers that: (a) provide critical new reviews; (b) present new science-based methodologies and field experiments; (c) offer new synthesis work in linking disparate findings across large regions of the world that help reconstruct Earth's land-surface hydrologic history; and (d) present applications of paleohydrological inference for mean values and extremes to disaster and water resources management.

The 22 papers in this issue represent time scales ranging from the past 100 years through the Late Pleistocene (30 ka BP) and Holocene (including the Medieval Climatic Anomaly and the Little Ice Age during the second millennium), and diverse hydrologic settings on several continents.

Papers are grouped roughly by the type of hydrological variable studied. Two papers focus on the reconstruction of precipitation or drought indices from stable isotopes in tree rings. $\delta^{18}O$ and $\delta^{13}C$ in tree-ring cellulose indeed can record fluctuations in moisture and thermal regime. Xu et al. develop the first well-replicated tree-ring $\delta^{18}O$ chronology in northern Thailand and apply this proxy to reconstruct precipitation for the period AD 1828–2000. The tree-ring $\delta^{18}O$ is closely related to Eastern Pacific ENSO from 1871 to 2000, with the exception of during the last two decades. The change may be related to southeastward shift of the descending limb of the Walker circulation since 1980 and increased frequency of Central Pacific ENSO. Tei et al. reconstruct summer Palmer Drought Severity Index in eastern Siberia since 1850 AD from $\delta^{13}C$ in larch tree rings. Differences in the persistence of reconstructed decadal-scale moisture anomalies at the study site and a location just a few hundred kilometers away are attributed to regional differences in moisture retention capability of the soil due to differences in soil carbon accumulation. The authors argue accordingly that regionally resolved paleoclimatic reconstructions are essential to precisely depict the spatio-temporal variability of drought in Siberia.

Paleofloods are addressed in five papers. In a review covering dendrogeomorphological as well as geomorphological techniques, which record floods in such features as slackwater deposits along streams and scars on trees, Bodoque et al. discuss challenges to paleoflood hydrology in mountainous watersheds. They stress the need to quantify and reduce uncertainty in paleoflood estimates. Ballesteros et al. apply dendrogeomorphological methods to unravel the history of flash floods and associated meteorological triggers in a mountain catchment in Spain. The reconstructed flash flood chronology combined with the existing flood record can be used to greatly improve delineation of flash flood hazard zones. In a second paper, Ballesteros et al. assess the use of tree-ring records of tree tilting for paleoflood discharge estimation. A mechanical root-plate rotational stiffness model is applied to pinpoint the correlation between the inclination of trees and flood magnitude. This new technique for flood peak-flows is a significant scientific and technical advancement in paleohydrological research. Therrell et al. explore the use of morphological changes in tree rings to extract a multi-century record of spring flooding along the Mississippi River. A novel annually-resolved tree-ring record of spring flooding based on anatomically anomalous "flood rings" is used to reconstruct past flood regime beyond the short instrumental record. Such reconstructions can provide clues to better understand the forcing of spring flooding. Paleofloods in the upper Hanjiang River Valley, China, on much longer scales (Holocene to Pleistocene) are addressed with the use of slackwater deposits (SWDs) by Huang et al. The estimation of minimum flood peaks ranging from 42,220 to 63,400 m^3/s provide a long-term context for improving the understanding of river system response to monsoonal climate variability in China.

Seasonal-total or annual-total river flows are the topics of five papers, four of which are based on tree-ring width data and one on stable isotopes in stalagmites. Lara et al. reconstruct more than 200 years of summer and early fall flow of the Baker River, Argentina and Chile, from widths of *Nothofagus pumilio* tree-rings. They find an unprecedented sustained decline in flows beginning in the 1980s, and suggest linkage of the trend to recent changes in the Southern Annual Mode of atmospheric circulation. DeRose et al. apply ring widths of *Juniperus osteosperma,* a tree species until now overlooked in dendroclimatology, to reconstruct annual flows of the Bear River, the largest river in the eastern Great Basin, USA.

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They report the last half of the 20th century as the 2nd wettest period of similar length in the last 1200 years. The contrast with what has been found with tree-ring data for the Colorado Basin serves as a caveat against generalizing proxy results over adjacent basins. Saito et al. illustrate use of tree-ring reconstructions of precipitation and temperature in combination with water-balance modeling to reconstruct flows of the West Walker River, California. The approach is recommended as an improved way of incorporating paleoclimatic data into streamflow reconstruction that allows investigation of influence on the reconstructed flow records of factors such as changes in land use and soil type. Sauchyn et al. address the application of dendrohydrology to water resource management, with examples from the western interior of Canada. Results demonstrate that a dense network of tree-ring chronologies is critical to downscale paleohydrological reconstructions to the time frame in which engineers and planners operate. The fact that government and industry would initiate and fund tree-ring research in the area highlights the growing recognition of paleohydrology as a legitimate technical support for water resource planning and management. The paper by Xu describes the use of a stalagmite oxygen isotope $\delta^{18}O$ record from a cave along the banks of a tributary of the Jialingjiang River, China, to reconstruct 5-year means of annual flow of the river and of basin-wide precipitation. A main feature in the resulting 1800-year reconstructions is a downward trend of river flow ca. AD 600–1600.

Variability in the hydrology of lakes and estuaries is the subject of six other papers. Using sedimentological, physical and geochemical proxy analyses of sedimentary cores, Guerra et al. reconstruct past hydrological scenarios for Lake Melincué, Argentina, back to AD 800. An abrupt shift from a wet period to drier conditions is shown to occur from the end of the Medieval Climatic Anomaly to the beginning of the Little Ice Age. Kaiser et al. combine tree-ring dating of submerged stumps with topographic mapping and analysis of aerial photos to derive extended records of levels of glacial lakes in north central Germany. While the record extension covers only the last ca. 100 years, the results reveal nonstationarity in the landscape water budget at a scale of decades that should be taken into account in climate impact studies. Mayr et al. apply oxygen isotope ratios of chironomids, aquatic macrophytes and ostracods to lake-water isotopic temperature reconstructions in Patagonia. The data suggests that $\delta^{18}O$ values of ostracods are less reliable than isotope ratios of chironomid head capsules as proxies of past host water conditions, and that $\delta^{18}O$ of aquatic cellulose is the most reliable proxy. Dean et al. compare isotope and chemical composition of lake water and sediments from a closed lake in central Turkey and address the implications of monitoring data for calibrating proxies to attain robust paleohydrological interpretation. Varved sediments give the opportunity for cross-checking of multi-proxy hydroclimatic change reconstructions through comparison of $\delta^{18}O$ from core sediments, trap sediments and water samples in specific years. Hepp et al. apply a coupled $\delta^{18}O$–$\delta^{2}H$ biomarker approach to reconstruct the last 16 ka (Late Glacial and Holocene) history of lake evaporation and the isotopic composition of precipitation in the High Himalaya, Nepal. Source determination of the sedimentary organic matter is assessed using a multi-proxy approach (pollen, C/N ratio, sugar biomarker composition). A model to reconstruct $\delta^{18}O$ and $\delta^{2}H$ values of paleo-precipitation is discussed. Isla et al. infer avulsion at a drift-dominated mesotidal estuary in Patagonia, Argentina, favored by the fluctuation of sea level and the longshore growing of gravel spits. Floodplain aggradation occurred during the last 8000 yr BP, but increased since the last 2,000 yr BP, when complex spits enclosed the outlet.

Sub-surface water is addressed by three papers. Creutzfeldt et al. propose a multi-disciplinary approach to reconstruction of subsurface water dynamics using hydrology, dendrochronology and geodesy. To illustrate the approach, an extended time series of water storage change is estimated from tree-ring widths of *Picea abies*, in combination with water-balance modeling and high-precision gravimeter observations from the Bavarian Forest, Germany. Pang et al. reconstruct paleo-environmental conditions from isotopes and hydrochemistry of groundwater from a basin in Northwest China. Air temperature and land cover are considered as the main forcings of isotope and water chemistry variability. The study has significant implications for groundwater management in the non-monsoon region of China, where groundwater has been severely exploited. Markowska et al. address influence of the hydrology of the unsaturated zone on cave drip water, and implications for paleoclimatic reconstruction from speleothems in Australia. A novel coupled hydrological box (reservoir-flows) and conceptual model is developed based on the relationships between surface inputs (rainfall and soil moisture balance), reservoirs and drip discharge responses. This contribution stresses the importance of understanding karst hydrology in disentangling isotopic and chemical signals preserved in speleothems and consequently on interpretation of the paleoclimate record.

In many parts of the world, the more recent part of the paleoclimatic record is overlapped by written documents. The value of documentary evidence to the reconstruction of hydroclimatic variability in central, northern and western Argentina is the theme of a paper by Prieto et al. Historic archives spanning the 16th to 20th centuries are analyzed to identify hydrological proxies (i.e., tithes, prices of agricultural products, evidence of property damage, among others). The article provides a summary of reconstructions covering the last few centuries in southern South America.

This special issue can of course only sample the vast and continually expanding research in paleohydrology. The set of selected papers deals primarily with water quantity – fluxes and storage – and does not tackle the question of long-term variability of water quality. The specified time frame of the Holocene excludes much interesting research on longer timescales.

Many challenges remain. Proxy data are estimates rather than measurements of the hydrologic variables of interest. The proxy source (tree ring, speleothem, lake records, etc.) is a natural filter which invariably imposes statistical distortion on the reconstructed variable. Better understanding and quantification of this distortion is needed, especially if reconstructions are to gain widespread use by agencies and other entities in water resources management and planning. While some types of proxy data have advantages over others for time coverage, temporal resolution, spatial coverage, or strength of hydrologic signal, no single proxy variable is best in all aspects. Paleohydrology is likely to rely increasingly on a multi-proxy approach, and the proliferation of regional studies will provide fertile ground for comparative and integrative analysis.

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