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# Editorial: Special Section on Visualization in Environmental Sciences

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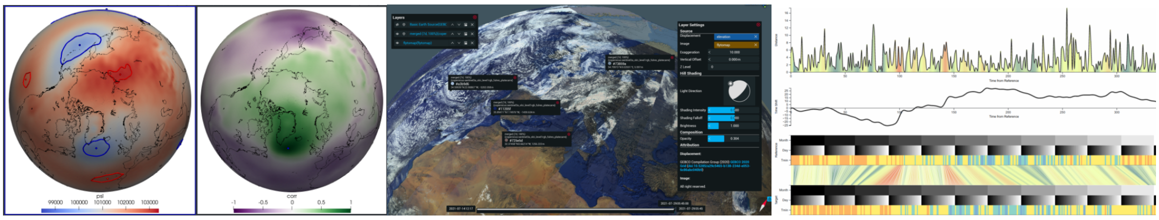
With the consequences of human-induced climate change becoming more and more visible over recent years, research in environmental sciences is becoming increasingly important, as we are faced with problems concerning extreme weather events, water scarcity, biodiversity changes, or environmental pollution. These topics that affect the entire population of the globe, from small to large scales. With the growing significance of research into this direction, both size and complexity of the underlying data are becoming larger and larger. At the same time, datasets are highly heterogeneous, with differences in structure, spatio-temporal resolution, scale, quality, and uncertainty.

For researchers, visualization is a vital component in the process of exploring and understanding phenomena described by such complex data. It can also support practitioners and stakeholders to make informed decisions, or help to inform the general public about environmental topics. However, due to the amount and the heterogeneous nature of the data, target-oriented visualization remains a complex task that requires state-of-the-art techniques to convey complex information in a comprehensible manner. The workshop on Visualization in Environmental Sciences has the goal to raise awareness to the importance of this topic, to establish a forum for interdisciplinary discussions and to give researchers the opportunity to present their work to a larger audience. It has been established in 2013 and is since then part of the annual EuroVis-Conference, the largest conference on visualization in Europe.

For this special section, the best submissions have been selected from the workshop hosted at EuroVis 2021 in Zurich, Switzerland, and the authors were invited to submit an extended and augmented version of their conference paper to Computers & Graphics. In addition, researchers could submit new articles to this special section. Each of the submissions were evaluated by at least three reviewers in a double-blind process. Based on their evaluation, the following six papers were accepted for publication in this special section:

Buck et al (2022) present the Digital Earth Viewer, a hybrid application that allows users to explore 4D geoscientific data via a web frontend in real time (Fig. 1b). Data is preprocessed and cached on a plug-in-oriented server backend. Using presentation layers, users are presented a GIS-like user interface for combining and exploring georeferenced data from heterogenous sources in 3D over time. As data sources, the authors are currently focussing on well-established formats such as netCDF, ESRI ASCII Grid, and CSV as well as a number of webservices. The application is used by marine researchers to plan exploration missions and as a presentation and data validation tool for the acquired data.

Another approach for visualising collections of heterogeneous data is presented by Rink et al (2022). Using an framework based on the Unity game engine, the interactive application visualizes a wide range of observation data and numerical simulations to construct a bigger picture for the understanding of (geo-)hydrological processes and the potential consequences of climate change. The case study presented here has been prepared in close collaboration with domain scientists and focusses on a small river catchment in Germany during a heavy rain event. It allows the concurrent visualisation of (observed) precipitation data and the subsequent



(a) Kappe et al (2022) (b) Buck et al (2022) (c) Urribarri and Larrea (2022)

Figure 1: Examples of visualization techniques presented in this special section.

(simulated) changes in soil moisture and groundwater in the context of topological information and a variety of measurement equipment.

de Souza et al (2022) investigate the evaluation of ensembles of weather simulations. Their visual analytics framework X-Weather is implemented in a web-based client-server-architecture and allows to explore statistics of and between ensemble members as well as investigate the probabilities of extreme weather events. Based on standard-formats such as netCDF or CSV, the data is visualized in a dashboard showing temporal overviews, GIS-like spatial views, as well as line charts representing, for instance, distributions or histograms. The system has been developed in close cooperation with experts, implementing a number of requested features required for everyday use.

On a similar topic, Kappe et al (2022) propose a framework for topological feature analysis in time-dependent climate ensembles (Fig. 1a). Using a number of established libraries ranging from NumPy to the Visualization- and Topology Toolkit, the authors devised modules as well as a visualization pipeline for feature detection, clustering, tracking, and variability analysis within very large climate simulation ensembles. Working together with domain scientists, the method was applied to detect and track important features such as the Azores High and the Icelandic Low, and the subsequent calculation of the North Atlantic Oscillation Index and may thus provide a useful approach for the future evaluation of other large ensembles.

The visualization technique presented by Urribarri and Larrea (2022) also deals with the comparison of meteorological datasets, especially focussing on large time series (Fig. 1c). Colour transfer functions are applied to represent distance functions of one dataset to another. In particular, the authors propose a so-called summary box matrix for a quick overview of pairwise comparisons of selected parameters over multiple years, as well as a detailed view, consisting of three techniques: a distance visualisation to judge how well two time series correspond and align, a representation of the misalignment function, and an approach to combine heat maps and a parallel time relationship visualisation.

Finally, the work by Lumley et al (2022) compares over 40 visualization tools for climate data and gives interesting insight into their purpose, what data is being incorporated, the visual representations used as well as the available options to interact with the data and the technologies used. Somewhat confirmed by the topics in this special section, they found that most climate visualizations focus on meteorological data and impacts. Interface complexity differs between exploratory and explanatory visualizations and applications are increasingly targeting non-scientists, such as decision makers or the public. Overall, this analysis can help to stimulate more discussions on the efficacy of climate visualization and (hopefully) improve their ability to address the rising challenges regarding climate change.

We are grateful that the Computers & Graphics journal provided this opportunity to publish a special section on the important topic of environmental data visualization. We would like to thank the authors for contributing and the reviewers for helping to ensure the quality of the manuscripts published here.

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# Editors

**Karsten Rink** is a postdoctoral fellow at the Helmholtz-Centre for Environmental Research (UFZ) in Leipzig, Germany. He studied computer science at the University of Leipzig and received his Ph.D. in Visual Computing from the University of Magdeburg, Germany. He is head of the Scientific Visualisation Group at the Department of Environmental Informatics at the UFZ and has been organising the EuroVis-Workshop on Visualization in Environmental Sciences since 2013. His research interests include the integration of heterogenous data collections as well as the immersive visualisation of environmental data. He is also a developer for OpenGeoSys, a software for the numerical simulation of processes in porous and fractured media.

**Kathrin Feige** works in the Meteorological Product Development and Distribution Systems Division at Deutscher Wetterdienst, the German national meteorological service. Here, she is primarily occupied with improving weather warnings. Accordingly, her research interests include the communication of (severe) weather events and of the uncertainty in their forecast. She received her Ph.D. in Computer Science from the University of Kaiserslautern, Germany. Since 2019, she is co-organizing the EuroVis-Workshop on Visualization in Environmental Sciences.

**Gerik Scheuermann** received a master degree (diplom) in mathematics in 1995 and a PhD degree in computer science in 1999, both from the Technical University of Kaiserslautern. He is a full professor at Leipzig University since 2004. He has coauthored more than 250 reviewed book chapters, journal articles, and conference papers. His current research interests focus on visualization and visual analytics, especially on feature and topology-based methods, flow visualization, tensor visualization, environmental visualization, document visualization, and visualization for life sciences. He has served as paper co-chair for Eurovis 2008, IEEE SciVis 2011, IEEE SciVis 2012, and IEEE PacificVis 2015, and he has been associated editor for major visualization journals including IEEE TVCG, CGF, and IEEE CG&A. He has co-organized TopoInVis 2007, AGACSE 2008, EuroVis 2013, EnvirVis 2013, EnvirVis 2014, and IEEE VIS 2018, as well as three Dagstuhl Seminars on Visualization. Currently, he chairs the EuroVis Steering Committee, and the EnvirVis Steering Committee. He will serve as general chair for EuroVis 2023.