**SECOND EDITION**

# HYDROLOGICAL DROUGHT

## Processes and Estimation Methods for Streamflow and Groundwater

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<u>Description</u>
Drought is a worldwide phenomenon that originates from a prolonged deficit in precipitation, often in combination with high evaporation, over an extended region. The resultant meteorological water balance deficit may cause a hydrological drought to develop and give rise to below normal levels of streamflow, lakes, soil moisture and groundwater. Hydrological drought can be aggravated (worsened) or alleviated (lessened) by human interventions. The focus in this state-of-the-art textbook is on streamflow and groundwater, as these are useful indicators of the available water resources in a region

or at a site. Meteorological water balance indices and soil water deficit indices are included to the degree that they support the understanding of hydrological drought. Socio-economic aspects are commented upon in the context of drought impacts and human influences on drought (socio-hydrology).

A key objective of this textbook is to contribute to increased knowledge and awareness of drought to a wide audience, hopefully encourage many more drought studies around the world, and thereby increase the preparedness and resilience of society to drought today and in a future climate.

## More information on:
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## What's different from the first edition?
This textbook builds upon the first edition (2004), which was compiled at a time when the literature available on hydrological drought still was limited. Since then, drought became prominent on the policy, water management and scientific agenda, and a large amount of knowledge and experience in various fields of drought analyses have accumulated in scientific journals, reports, and technical manuals. After nearly 20 years, there was a need to again collate, review and supplement this material, and subsequently present a synthesis of the current knowledge on hydrological drought in one volume. A next generation of drought experts joined the author team bringing in new knowledge and experience.

In this second edition, existing chapters have been significantly updated and new content added (i.e., on hydroclimatology, drought-generating processes, hydrological data, hydrological drought characteristics, frequency analysis, statistical analysis of drought series, regionalisation procedures - estimation at the ungauged site, and human influence). New chapters are added, including: (a) past and future drought to better understand drought behaviour across time, including observed trends and future changes, (b) drought impacts to support drought vulnerability assessment and drought risk management, and (c) drought early warning systems to support monitoring, forecasting, communication.

Knowledge and experiences shared in this textbook are from regions all over the world. International literature has been synthesised and authors' experiences from drought projects and international initiatives, including global networks, have assisted in giving this textbook a wider scope. [Select other topic]

## Content
The book is divided into three parts. The drought phenomenon, its main features, regional diversity and controlling processes are discussed in general terms in Part I (Drought as a natural hazard).

Part II (Estimation methods) presents contemporary approaches to drought estimation, and methods and calculation details are demonstrated using the example datasets provided on a GitHub repository 'HydroDrought' specifically designed for this textbook (https://github.com/HydroDrought/hydrodroughtBook). Emphasis is given to estimation methods applied to time series of hydrometeorological variables and estimation of drought indices at the gauged and ungauged site. Alongside this, recommendations and possible limitations for application are given.

Part III (Living with drought) addresses aspects related to the interactions between water and society and are of an interdisciplinary character. Topics include historical and future drought, human

influence on drought, the wide range of drought impacts encountered and drought early warning systems (monitoring and forecasting).

All chapters conclude with a short summary, which highlights the main issues and recommendations given in each chapter followed by a list of recommended further reading. The book contains in total 13 chapters and is structured as follows:

*Part I: Drought as a natural hazard*
1 Introduction
2 Hydroclimatology
3 Drought-generating processes

*Part II Estimation methods*
4 Hydrological data
5 Hydrological drought characteristics
6 Frequency analysis
7 Statistical analysis of drought series
8 Regionalisation procedures e estimation at the ungauged site
9 Process-based modelling

*PART III Living with drought*
10 Human influence
11 Past and future hydrological drought
12 Drought impacts
13 Drought Early Warning Systems: monitoring and forecasting

The textbook is easily accessible with a consistent structure, terminology and a coherent content across chapters (i.e. data, processes, analysis tool, applications) with backward and forward referencing.
[Select other topic]

## Additional features

The main text is supported with text boxes, worked examples, case studies, self-guided tours, appendices, supporting documents and supporting code.

- *Text boxes* present details on a specific topic as an addition to the information given in the main text.
- *Worked examples* are sample methods that are demonstrated in a stepwise manner using data and tools available on GitHub[1] (https://github.com/HydroDrought/hydrodroughtBook). They enable the reader to repeat the calculations, either with their own data or by using the time series included with this textbook.
- *Case studies* present the application of a method to a specific region or site and includes a discussion of the results.
- *Self-guided tours* are demonstrations of advanced methodologies that involve several calculation steps and are given as PowerPoint presentations on GitHub.
- *Supporting Documents* and *Supporting Code* provide additional details of a method or modelling tool. The Supporting Documents and Supporting Code are available on GitHub.

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[1] The material on GitHub is organised by category (e.g., data, worked example) and chapter, and the user is guided by a navigation procedure.

A *glossary* provides an overview of drought terminology used throughout this textbook. The terminology builds upon the Handbook of Drought Indicators and Indices by World Meteorological Organization (WMO) and Global Water Partnership (GWP), Factsheets from the European and Global Drought Observatories, and the Intergovernmental Panel on Climate Change (IPCC) Glossary.

Four *datasets* are included on GitHub: an international, a regional and two local datasets. These data constitute the basis for the majority of the examples presented in this textbook. The drought phenomenon and its diversity across the world are illustrated using an international dataset, whereas regional data and local aspects of drought are studied using a combination of hydrological time series and catchment information.

[Select other topic]

## Readership

Hydrological Drought - processes and estimation methods for streamflow and groundwater - is a textbook for university students, practising hydrologists, lecturers, and researchers who are engaged in the analysis of hydrological drought and its prediction in the current and future climate. The aim is to provide background knowledge and understanding of the drought phenomenon and give the reader a comprehensive overview of methods and tools to estimate and manage hydrological drought (streamflow and groundwater). It includes a qualitative, conceptual understanding of drought features and processes, a detailed presentation of estimation methods and tools, practical examples, and key aspects of how to live with drought under global change. Basic requirements are introductory courses in hydrology and statistics. The first three chapters (Part I) are descriptive and of an introductory nature and are therefore suited for undergraduate level. The material in Part II (Chapters 4-9) is more advanced and aims at the graduate level. Most parts of Part III (Chapters 10-13) are at the graduate level. We trust that this textbook can benefit both professionals and students all over the world by providing increased knowledge and understanding of the drought phenomenon.

[Select other topic]

## Contributors

The following drought experts (in alphabetic order) contributed to the book: Lucy J. Barker, Veit Blauhut, John P. Bloomfield, Carmelo Cammalleri, Kolbjørn Engeland, Nick Everard, Katie Facer-Childs, Miriam Fendeková, Matthew Fry, Tobias Gauster, Jamie Hannaford, Shaun Harrigan Hege Hisdal, Monica Ionita, Daniel G. Kingston, Gregor Laaha, Terry Marsh, Katie Muchan, Cosmo Ngongondo, Simon Parry, Christel Prudhomme, Gwyn Rees, Eric Sauquet, James H. Stagge, Kerstin Stahl, Lena M. Tallaksen, Albert I.J.M. Van Dijk, Henny A.J. Van Lanen, Anne F. Van Loon, Jean-Philippe Vidal, Jürgen Vogt, and Niko Wanders.

The majority of the authors are members of the international FRIEND-Water (Flow Regimes from International Experimental and Network Data) project, a contribution to UNESCO's Intergovernmental Hydrological Programme (IHP). The idea of compiling a second edition of the textbook on hydrological drought emerged in FRIEND-Water Low Flow groups as a result of many years of close cooperation in drought research. The authors also benefited from cooperating in other networks, such as Drought in the Anthropocene (Panta Rhei) and Prediction in Ungauged Basins (PUB), both initiatives under the International Association of Hydrological Sciences (IAHS).

[Select other topic]