INTRODUCTION AND OVERVIEW OF PAPERS IN THIS SPECIAL ISSUE OF WATER POLICY

Alfred North Whitehead, a co-author of ‘Principia Mathematica’ with Lord Bertrand Russell, once stated an obvious pragmatic principle for dealing with change and uncertainty: ‘the art of progress is to preserve order amidst change – and change amidst order’ (Whitehead, 1929). Climate change, and its numerous associated uncertainties, impinges on virtually every aspect of water resources planning, management, design and operations.

At the same time, many other profound societal changes are simultaneously superimposed on the water resources management community such as changing demographics and demands, technological innovation, along with evolving environmental, economic and social well-being goals. Under these multiple sources of change, professional water management practitioners strive to maintain an orderly pace of innovation and integration of modern analytical techniques amidst rapid societal changes and political pressures emerging from the climate mitigation community. On the other hand, public and politicians demand rapid changes in decision processes and outcomes, within what they perceive are fairly slow and relatively inflexible institutional decision frameworks of agencies and ministries.

Water resources and coastal protection infrastructure systems represent the basic components of structural and non-structural adaptation to future uncertain impacts of climate change. It is evident from the most recent IPCC report (2021), and the outcomes of COP 26 (UNFCCC Conference of Parties, 2021) that many nations are having difficulties fulfilling their greenhouse gas reduction commitments made at the Paris Climate Convention in 2015. Temperatures will continue to rise, as greenhouse gas reduction mitigation efforts falter. Adaptation, then, stands as a practical response to the international community’s failure to coalesce around their climate mitigation strategy and goals.

It is estimated by the Inter-American Development Bank (IDB, 2017) that between 2015 and 2030, $90 trillion in new infrastructure investments will be needed. This amount is equivalent to the world’s total existing stock. Much of the world’s new infrastructure will be built in developing nations. As these nations work to address widespread poverty and build thriving economies, they will be facing daunting challenges such as responding to natural hazards and rapid urbanization. These circumstances present opportunities to design sustainable and robust infrastructure that also serves fundamental climate adaptation objectives, forming the basis of a ‘no regrets’, cost-effective response to climate change.

The issues examined within this volume are essentially policy-driven issues that require engineering solutions. The articles offer practical responses to the fundamental question: How does society, and its numerous institutions and decision-making authorities, go about making communities more ‘resilient’ and ‘robust’ in the face
of large uncertainties associated with climate change, along with other major determinants of growth and development such as population increases, globalization and economy, and regional population shifts? Upgrading resilience and robustness relies, inherently, on a series of innovative climate adaptation measures that can accommodate the uncertainties associated with these major external forces that affect every community throughout the globe.

The major determinants of growth and development are largely external in nature such as climate, population shifts and economic forces. Most decisions affecting community resilience and robustness are endogenous forces such as local land use regulations, zoning decisions, building codes and other agreed-to goals, incentives and constraints that shape the political response of communities to a variety of factors related to preferred growth and development pathways, as well as to natural phenomena and socio-economic trends.

Many agencies, ministries and multilateral lending institutions are all struggling with the similar problem of how to effectively deal with numerous uncertainties without spending excessive sums on peripheral studies and needlessly protracting the time for decisions. Usually, many critical infrastructure investment decisions such as rebuilding after each natural disaster need to be made presently. However, the quantitative tools required for such decisions are not yet ready for ‘prime time’ (Kundzewicz & Stakhiv, 2010). More importantly, the information generated by such complex technical analyses is often not suitable or readily understandable by the ultimate decision-makers and politicians who authorize and fund large infrastructure projects and systems. In short, institutions and agencies have struggled to find sensible ways to ‘work around’ the many conceptual and technical problems posed by the lack of knowledge. And, paradoxically, also contending with a myriad of untested methods and decision frameworks that have sprung up to deal with climate uncertainties.

Institutions and their administrative procedures are the governors and gyroscopes of change. Institutions possess grave responsibilities to the societies and communities that they serve. Hence, ‘public engineering’ is built not only on the foundations of science, data, empirical evidence and models, but also on a millennia-long evolutionary experience with natural disasters, engineering failures and addressing societal needs in a reliable manner (Petroski, 2006). Experience based on failures is the most fundamental and reality-based peer review that guides the engineering profession.

Planning procedures, engineering design standards and codes represent the core of institutional procedures that reflect a continuous evolutionary trend of learning from disasters and their accompanying infrastructure failures (Petroski, 2006). Natural disasters and extreme hydroclimatic conditions form the basis of engineering responses by the water resources management sectors, and that are also required for a pragmatic climate adaptation strategy. They comprise the core of contemporary ‘best management practices’ that are constantly evolving, keeping pace with societal adaptation mechanisms to accelerating global changes linked to trade, regional conflicts, energy shortages, poverty, pandemics and economic instabilities.

Infrastructures are key components that underly the stability and sustainability of communities. They are means to enhance reliability and robustness, to cope with unexpected natural hazards, and to build resilience to bounce back in the aftermath of a disaster. Without water treatment facilities, reliable power grids, adequate transportation networks, communications network or adequate flood control, how do communities grapple with and endure the effects of a natural disaster? How do societies go about retrofitting existing infrastructure to deal with future unknown climate vagaries, combined with uncertain economic and demographic changes? Who determines when and how to undertake innovative analyses that will be required for planning for future hazards? What should be the new standards for infrastructure design to increase future capacity and reliability, as well as robustness and resilience, the ability to withstand unknown forces and the ability to rebound more quickly after a disaster? What does ‘climate-resilient’ infrastructure look like, and how does it differ from contemporary infrastructure design that is inherently aimed at withstanding a wide range of external forces (Hill et al., 2019)?
These are the questions that the papers in this volume address. Multi-national lending institutions, such as the World Bank and the Asian Development Bank, who work mostly in developing nations, together with leading national water infrastructure engineering agencies, such as the U.S. Army Corps of Engineers, the Bureau of Reclamation, Japan’s Ministry of Land, Infrastructure and Transportation, and Holland’s Rijkswaterstaat, have been addressing these issues as part of their updated approaches to climate adaptation. They stand in the forefront of finding practical solutions to a broad range of perplexing analytical problems. Together, they have developed several comparable variants of a tiered approach to planning, design and decision-making for practically considering the superposition of climate uncertainties over the ever-present suite of demographic, economic and sociocultural uncertainties that normally form the basis of long-term planning in the nations with which they work.

ORIGINS OF THE PROJECT

The UN Secretary General’s Advisory Board (UNSGAB) and High Level Exert Panel on Water and Disasters (HELP) was mobilized to provide expert advice to the many nations, particularly developing nations, confronted with the increased frequency and intensity of climate-related disasters. The HELP ‘Action Plan’, developed in 2009, had 6 major themes and 40 actions. UNSGAB Action 29 reads as follows:

‘National and international hydrological institutes must take the initiative to identify underlying analytical and data requirements to meet climate changes that are likely to be highly uncertain and so as to support structural and non-structural measures for disaster risk deduction’.

‘UNESCO-ICIWaRM and U.S. Army Corps of Engineers Institute for Water Resources are given responsibility for implementing Action 29, in conjunction with ICHARM and other world-renowned Institutes’.

The overall goal of this collaborative effort between UNSGAB HELP and UNESCO-based institutions was to examine and recommend new practical risk-based planning methods, analytical approaches and criteria associated with engineering design standards and guidelines for water resources infrastructure planning and design. Specifically, the goal was to focus on those procedures currently in use, that could be readily adapted, upgraded or extended by various agencies and ministries, such as the Bureau of Reclamation, Rijkswaterstaat, Corps of Engineers or the Bangladesh Water Development Board, to better accommodate realistic considerations of future climate uncertainties and other rapid societal ecological, and economic changes.

This project simultaneously fulfilled an important component of the eighth phase of the International Hydrological Program (IHP-VIII) conducted by UNESCO. This IHP (2014–2021) program has the overall theme of: ‘Water security: Responses to local, regional, and global challenges’ http://www.iciwarm.org/en/docs/Appendix_EXECUTIVE_SUMMARY_OF_IHP_VIII.pdf.

As part of the IHP-VIII initiative, UNESCO-ICIWaRM engaged several other UNESCO Centers to carry out this effort, including ICHARM (International Center for Water Hazard and Risk Management in Japan), and ICWRGC (International Centre for Water Resources and Global Change, Cologne, Germany) and WMO. Three technical workshops were held at ICIWaRM and ICWRGC as part of this effort, designed to lay out the key issues and methods available for a risk-based approach to analysis. Nearly 50 participants discussed the major themes that were of concern to the engineering profession and practitioners. Papers were solicited from many participants and they reflect the major themes that were discussed at these workshops.

OVERVIEW OF CONCEPTS

The overall aim of this collection of papers is to provide additional practical intellectual grounding to selected advances that are already in place and practiced by leading institutions, and others that could readily be adapted
by the water resources engineering profession to better deal with risk and uncertainty in a non-stationary climate world. This volume does not present original research, as such, since the focus is on synthesizing promising best management practices and existing ideas that have been developed over the past decade, since UNSGAB’s directives, and relevant published research that has not yet been incorporated into the body of institutional ‘best management practices’. These practices exist in legally binding forms of engineering regulations, manuals and design standards of the water resources engineering institutions, agencies, ministries and professional societies. The papers represent an explication of, and search for appropriate engineering solutions to fundamental policy questions surrounding climate change and adaptation.

A wide range of existing hydrologic planning and design frameworks and methods were considered, ranging from deterministic to probabilistic-based design approaches and criteria for water supply, flood control infrastructure, hydropower, hurricane protection, etc. There are three overlapping themes, reflecting the title of the special volume. How the planning and design practices of the three primary functions of water resources, such as planning, design and management, can be modified to reinforce climate adaptation solutions. The three clusters of papers in this Special Issue reflect those themes.

The first group of papers examines several comparable project planning and evaluation frameworks that treat climate uncertainties and non-stationarity within existing traditional project justification frameworks used by the World Bank, the Asian Development Bank, the Corps of Engineers and other comparable national agencies. The planning frameworks are important because they reflect a common set of policies related to climate adaptation, which are transformed into principles and guidelines for dealing with climate uncertainties and how practically and cost-effectively to analyze the reliability, resilience and robustness of proposed systems and projects.

The second group of papers reviews existing engineering design standards and risk-based procedures for updating those standards by various agencies in the EU, the US and Japan. This set of papers provides case study examples of variations of risk-based approaches to upgrade design standards. One of the central confounding issues is how to quantitatively define the risks of an essentially unknowable non-stationary climate. The principal way that the engineering profession has dealt with this dilemma is to focus on quantifying hydroclimatic extremes, and assigning probabilities to empirically derived estimates. Designs are then based on both extremes and added safety factors to accommodate known and unknown uncertainties. Hurricane Katrina reconstruction is offered as a prime case study example of innovative risk-based design methods used to upgrade the New Orleans hurricane protection system.

The third cluster of papers examines additional analytical innovations that should be considered or need to be developed in the near future to improve planning and design. They cover different decision criteria, such as satisficing, which would be required for evaluating projects under climate uncertainty, instead of relying on traditional economics and the benefit–cost paradigm. Also presented is the need for drought frequency analytical standards to complement existing flood frequency analysis standards. Another paper discusses adaptation pathways needed for capacity expansion of existing infrastructure. In the vitally important management function of operating existing water storage systems, the viability of methods is discussed for incorporating decadal climate variability (DCV) information as an aid to seasonal forecasts.

Most papers in this Special Issue are focused on specific methodologies and quantitative techniques for making better estimates of risk and uncertainty for key underlying hydrologic phenomena and decision criteria. However, these analytical methods are necessary inputs to broader evaluation and decision frameworks that societies have structured to assist in making sensible, normative, unbiased, and uniformly applied and socially acceptable decisions. Such frameworks are underlain by traditional and well-accepted economic and engineering decision criteria, many of which are embedded within law and agency regulations.
INSTITUTIONAL EVALUATION AND DECISION FRAMEWORKS

The first series of papers spotlight the encompassing project evaluation and decision frameworks of major infrastructure planning and financing institutions, such as the World Bank and the Asian Development Bank, and of national approaches, such as those of Japan and the US. These frameworks evolved from a series of policy directives which attempted to integrate climate change and its uncertainties within each institution’s existing planning and design guidelines. The important distinction is that the multilateral international lending institutions deal with the developing world. It is there that innovative, cost-effective and climate-resilient adaptation technologies will have the greatest beneficial economic impacts. New methods and technological solutions can more easily ‘leap-frog’ outdated traditional approaches in these settings. In contrast, retrofitting existing infrastructure in densely populated urban areas is very costly, and will be a challenge for the developed nations of the EU, Japan or the US.

The papers are:

1. ‘Towards Pragmatism in Climate Risk Analysis and Adaption’, by R.L. Wilby, X. Lu, P. Watkiss and C.A. Rodgers
2. ‘Water-Related Infrastructure Investments in a Changing Environment: A Perspective from the World Bank’, by D.J. Rodriguez, H.A. Paltan, L.E. Garcia, P. Ray and S.S.G. Freeman
3. ‘Climate Risk-Informed Decision Analysis [CRIDA]: “Top-down” vs “Bottom-up” Decision Making for Planning Water Resources Infrastructure’, by J. Manous and E. Stakhiv
4. ‘Evolution of Japan’s Flood Control Planning and Policy in Response to Climate Change and Social Changes’, by T. Koike

Except for Japan, the papers present fairly similar evaluation frameworks that have practically sorted through a bewildering array of various climate modelling approaches, analytical techniques for non-stationary hydrologic analysis, and planning evaluation approaches that were devised to elucidate climate uncertainties. In turn, this array of methods has created additional challenges with associated uncertainties (Slater et al., 2021), that include the following:

• Downscaling a multitude of climate scenario precipitation and temperature outputs and transforming into hydrological outputs (runoff and flood and drought frequencies)
• Dealing with non-stationary climate signals with standard frequency-based hydrologic analysis that are currently the basis for project economic justification and design
• Adapting existing planning evaluation approaches that are not readily suited for dealing with large magnitude climate uncertainties
• Designing and economically justifying robustness and resilience for water projects under conventional economic project evaluation and justification procedures and criteria.

Each of the papers in this group covers each institution’s transition from a ‘top-down’ climate scenario-driven approach to a more traditional ‘bottom-up’ vulnerability assessment decision approach. Each institution has developed a hierarchical tiered approach to deciding how much climate-related analysis is required, and under what circumstances. The paper by Wilby et al. focuses on Asian Development Bank’s (ADB) practical approaches that are focused on ‘delivering project outcomes despite climate change’. ADB developed a climate risk management framework that screens projects for climate risks across the entire project development cycle.

The paper by Rodriguez et al. reflects the World Bank’s approach to support climate-informed project investment decision making. The core of the World Bank approach is a hierarchical four-phase ‘Decision-Tree Framework (DTF)’ that helps to screen projects for vulnerabilities and analyze plans and determine whether
and which risk management options may be suitable. It is a similar process to the one described by the ADB, using a ‘bottom-up’ approach and a series of ‘stress tests’ that determine how much detail is warranted for ‘top-down’ climate-related analysis. The Rodriguez et al. paper provides several case studies as examples of the application of their ‘DTF’.

The paper by Manous and Stakhiv presents another variant of the ADB and WB approach, termed as Climate Risk-Informed Decision Analysis (CRIDA). It is comparable to both, but follows the World Bank DTF model more closely. However, the paper delves more deeply into specific evaluation and decision characteristics that are associated with the traditional U.S. water resources planning paradigm used by federal agencies, and provides more qualitative guidance on the circumstances under which ‘bottom-up’ or ‘top-down’ climate analysis may be required for the various traditional functions of water management, such as project planning, design, operations and river basin portfolio analysis. CRIDA also promotes a variant of a pragmatic climate adaptation approach that expands on the notion of incremental capacity expansion, through a process called ‘adaptation pathways’.

Koike’s paper overviews a more traditional evolution of Japan’s policies and planning approaches in response to climate change risks and social changes. Japan’s approach was to base their new flood risk guidelines on traditional empirical data and recalculated extreme floods, conditioned on the potential impacts associated with climate model representative concentration pathway scenarios of RCP 2.6 (low forecast) and RCP 8.5 (high forecast). Japan, which is subjected to frequent extreme floods that are accentuated by its steep topography, undertook a thorough analysis of its watersheds, updating hydrologic information and revised its design criteria for 15 regions.

**RISK-BASED ENGINEERING DESIGN STANDARDS**

The second group of papers highlights the important role and evolution of risk-based engineering design standards in dealing with the extremes of contemporary climate, and how they could be updated to encompass climate non-stationarity. Several of the authors have argued that these updated standards can readily serve as the basis for dealing with many of the uncertain trends associated with climate non-stationarity. The practices of the EU, Japan and the US are highlighted, with case studies of engineering design progressively adapting to the growing extremes of climate non-stationarity, with significant adjustments made after each natural disaster.

5. ‘Climate Change Adjustments in Engineering Design Standards. European perspective’, by Z.W. Kundzewicz and Paul Licznar
6. ‘The Centrality of Engineering Codes and Risk-Based Design Standards in Climate Adaptation Strategies’, by E.Z. Stakhiv
7. ‘Anticipated Maximum Scale Precipitation for Calculating the Worst-Case Floods’, by K. Takeuchi and S. Tanaka
8. ‘Screening for Non-Stationary Analysis’, by P.H. Kirshen
9. ‘Hurricane Katrina and New Orleans: A Forensic Assessment – Part 1’, by L.E. Link
10. ‘Designing the Hurricane Storm Damage Reduction System and Resulting Long-Term Engineering Guidance and Practice Changes – Part 2’, by L.E. Link

Kundzewicz and Licznar’s paper provides an overview of progress made by the European Union to grapple with developing a common approach to climate uncertainties and adaptation. A review of progress shows that though EU member states have devised qualitative national flood risk management objectives and have delineated adaptation measures that address those objectives, they are still far from implementing a consistent and uniform system among member states. The authors provide an array of readily attainable advances in climate-driven risk-based adjustments of urban and transport drainage design standards and ‘design floods’ for major flood protection infrastructure. They conclude that advances in hydrological sciences and climate science must...
ultimately be ‘translated into acceptable and replicable engineering design standards’ and commonly used methods for dealing with climate non-stationarity.

Stakhiv’s paper emphasizes the same message as Kundzewicz and Licznar: that since engineering codes, design standards and analytical criteria for hydraulic structures are the final determinative specifications for designing and constructing a water resources project, they are the authoritative and legally accepted standards for project design and construction. Stakhiv stresses that these standards are updated regularly by most developed nations, especially after major disasters. Because they are based on considering extreme climate conditions, they can serve as a reliable platform for the next phase of updated risk-based standards to deal with future climate uncertainties. This is important, because the standards of such developed nations as the US, Japan and the Netherlands, which experience numerous hydrologic hazards and hydraulic failures, serve as the basis for international standards. Stakhiv concludes that contemporary risk analysis methods and risk-based standards, codes and methods comprise an important part of a progressive autonomous adaptation to climate change. They represent an essential component of ‘no-regrets’ climate adaptation.

The paper by Takeuchi and Tanaka details how Japan’s new flood risk standards were developed in support of Japan’s 2015 Flood Risk Management Act. This Act was also covered in Koike’s paper. As a policy statement, the Japanese government decided that saving lives was the top priority, so the hydrologists and engineers developed a ‘worst-case scenario’, based mostly on empirically calculated precipitation maxima, anticipated maximum scale precipitation, for 15 climatologically uniform regions. Using this new data, Japan revised all their flood hazard maps. The hydro-climatological outputs of climate scenarios were referenced to better understand where the empirically derived maximum precipitation estimates lay within the envelope of possible future climate outcomes.

Kirshen’s paper addresses the important question of how and when to formally consider climate non-stationarity as part of project planning. This key analytical issue was raised in many of the papers, with different perspectives. Kirshen provides a set of practical common-sense suggestions on identifying the circumstances for either side-stepping the need for employing specific methods to quantitatively represent non-stationarity, or situations where it is essential to explicitly consider non-stationarity.

Link’s two papers on the post-flood engineering analysis associated with Hurricane Katrina describes a major inflection point in the evolution of risk-based engineering standards for flood protection. Hurricane Katrina was a four-fold extreme event: storm surges, wind damage, severe flooding and considerable loss of life. Part 1 describes the damage to the existing system, through the various stages of flooding and storm surges. Part 2 covers the extensive and innovative risk and reliability analysis that was undertaken as part of the design for a substantially upgraded storm surge and flood protection system. It resulted in a major overhaul of many engineering regulations and design manuals of the Corps of Engineers, which the author enumerates.

**FURTHER ADVANCES AND CHALLENGES**

The third group of papers addresses additional evaluation perspectives and prospective analytical needs for continuing research, development and applications that will further assist planners and design engineers in dealing with climate change uncertainties.

11. ‘Infrastructure Capacity Planning for Reducing Risks of Future Hydrologic Extremes’, by J.J. Boland and D.P. Loucks
12. ‘Flood Risk Management in Changing Time’, by G.B. Baecher and G.E. Galloway
13. ‘On the Need for Guidelines for Streamflow Drought Frequency Analysis’, by R.M. Vogel and C. N. Kroll
14. ‘Incorporating Decadal Climate Variability Information in Operation and Design of water Infrastructure’ by J.R. Olsen, V.M. Mehta and H. Hill
Boland and Loucks tackle the important concept of infrastructure capacity expansion as a practical way of coping with climate uncertainties associated with the extremes of floods and droughts and keeping pace with climate signals as they become evident. Capacity expansion is inherently a central feature of adaptive management, and ways of determining the best time sequence for implementing the increments of capacity expansion. The authors review several traditional approaches to capacity expansion, along with more innovative approaches to adaptive capacity planning.

In a similar vein, Baecher and Galloway consider the traditional regulatory and policy approach to flood risk management, and find it deficient in dealing with climate uncertainties. They argue that because of the uncertainties involved, it is unreasonable to assign probabilities to future events, making it very difficult to employ traditional economic optimization methods. Instead, they advocate using a satisficing approach. These are satisfactory solutions that do not undergo economic optimization tests, but address a series of risk reduction factors that increase robustness and resilience in a cost-effective manner.

Vogeland Kroll tackle the need for streamflow drought frequency guidelines to complement existing flood frequency guidelines and standards. Existing flood frequency guidelines provide uniformity for U.S. federal agencies in design, flood insurance programs and management of existing flood control systems. The authors argue that drought frequency guidelines are needed to manage comparable multi-billion dollar crop insurance programs of the U.S. Department of Agriculture and many other existing drought compensation programs. Coordinating the U.S. Federal Government and State government drought management programs for pollution control, ecological purposes and municipal and industrial water supply require a consistent analytical approach to drought analysis.

Olsen, Mehta and Hill cover the important topic of seasonal forecasts that rely on Decadal Climate Variability (DCV) projections for improving reservoir management and operations, especially a system of reservoirs. While substantial advances have been made in drought forecasting, because of the persistence of droughts, the authors conclude that much more research is needed to overcome Type I (false positive) and Type II (false negative) errors associated with such forecasts. If DCV indices indicate that the climate has a higher probability of dry conditions, drought contingency plans could be triggered earlier. Understanding DCV phenomena could also improve long-range water resources planning. The authors provide several case studies about the relative effectiveness of employing DCV indices, and the research gaps that still exist.

**DATA AVAILABILITY STATEMENT**

All relevant data are included in the paper or its Supplementary Information.

**REFERENCES**

Hill, A., Mason, D., Potter, J., Hellmuth, M., Ayyub, B. & Baker, J. (2019). *Ready for Tomorrow: Seven Strategies for Climate-Resilient Infrastructure*. Hoover Institution, Washington DC.

Inter-American Development Bank (IDB) (2017). *Inter-American Development Bank Sustainability Report 2017*. p. 68. http://dx.doi.org/10.18235/0001034. Available at: https://publications.iadb.org/publications/english/document/Inter-American-Development-Bank-Sustainability-Report-2017.pdf.

IPCC (2021). Climate change 2021: the physical science basis. In *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M. I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J. B. R., Maycock, T. K., Waterfield, T., Yelekçi, O., Yu, R. & Zhou, B., (eds). Cambridge University Press, Cambridge, UK, In Press.

Kundzewicz, Z. & Stakhiv, E. (2010). Are climate models ‘ready for prime time’ in water resources applications, or is more research needed? *Hydrological Sciences Journal* 55(7), 1085–1089. doi:10.1080/02626667.2010.51311.

Petroski, H. (2006). *Success Through Failure: The Paradox of Design*. Princeton University Press, Princeton, NJ, p. 256.
Slater, L., Anderson, B., Buechel, M., Dadson, S., Han, S., Harrigan, S., Kelder, T., Kowal, K., Lees, T., Matthews, T., Murphy, C. & Wilby, R. (2021). Nonstationary weather and weather extremes: a review of methods for their detection, attribution and management. Hydrology and Earth System Sciences 25, 3897–3935. https://doi.org/10.5194/hess-25-3897-2021.

UNFCCC Conference of Parties (2021). 26th UN Climate Change Conference of the Parties (COP26), Glasgow, 31 October–13 November 2021.

Whitehead, A. N. (1929). Process and Reality: An Essay in Cosmology. Available at: https://en.wikipedia.org/wiki/Process_and_Reality

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