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Advances and challenges in the water sciences in Brazil: a community synthesis of the XXIII Brazilian Water Resources Symposium

Avanços e desafios da ciência de recursos hídricos no Brasil: uma síntese comunitária do XXIII Simpósio Brasileiro de Recursos Hídricos

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ABSTRACT

In this paper we synthesize the special sessions of the XXIII Brazilian Water Resources Symposium 2019 in order to understand the major advances and challenges in the water sciences in Brazil. We analyzed more than 250 papers and presentations of 16 special sessions covering topics of Climate Variability and Change, Disasters, Modeling, Large Scale Hydrology, Remote Sensing, Education, and Water Resources Management. This exercise highlighted the unique diversity of natural and human water features in Brazil, that offers a great opportunity for understanding coupled hydrological and societal systems. Most contributions were related to methods and the quantification of water phenomena, therefore, there is a clear necessity for fostering more research on phenomena comprehension. There is a vast network of co-authorship among institutions but mostly from academia and with some degree of regional fragmentation. The ABRhidro community now has the challenge to enhance its collaboration network, the culture of synthesis analysis, and to build a common agenda for water resources research. It is also time for us to be aligned with the international water science community and to use our experiences to actively contribute to the tackling of global water issues.

Keywords: Brazilian water community; Knowledge building; Research agenda.

RESUMO

Este artigo apresenta uma síntese das sessões especiais do XXIII Simpósio Brasileiro de Recursos Hídricos 2019, com o objetivo de compreender os principais avanços e desafios em recursos hídricos no Brasil. Foram analisados mais de 250 trabalhos e apresentações em 16 sessões especiais abrangendo temas como Variabilidade e Mudanças Climáticas, Desastres, Modelagem, Hidrologia de Grande Escala, Sensoriamento Remoto, Educação e Gestão de Recursos Hídricos. Esta avaliação destacou a diversidade única de atributos naturais e antrópicos dos recursos hídricos brasileiros, que oferece uma grande oportunidade para aprendizado sobre sistemas hidrológico e humano acoplados. A maioria das contribuições é relacionada a métodos e quantificação de fenômenos hídricos, existindo uma necessidade clara de incentivo a mais pesquisas em compreensão de fenômenos. Existe uma vasta rede de coautores, mas principalmente da academia e com certo grau de fragmentação regional. A comunidade da ABRhidro tem o desafio de aumentar a sua rede de colaboração, a cultura de análises de síntese, e construir uma agenda comum para a pesquisa em recursos hídricos. Também é o momento de alinhar esforços com a comunidade de recursos hídricos internacional, usando nossas experiências para contribuir ativamente na solução de questões relacionadas à água em nível global.

Palavras-chave: Comunidade brasileira da água; Construção do conhecimento; Agenda de pesquisa.

INTRODUCTION

Most advances in the water sciences were driven by practical societal needs regarding water resources (Sivapalan & Blöschl, 2017). The understanding of the interaction of water and society is key for both advancing the science and for guaranteeing water security (Lall, 2014; Sivapalan & Blöschl, 2017), especially in the Anthropocene where the human footprint is expanding in the hydrological cycle. As the challenges related to water security become more complex (e.g., climate change, population growth, land use change, physical and virtual water transfers), a clear and common scientific agenda is required to understand the possible consequences induced by society in the hydrologic cycle (Blöschl et al., 2019a; Lall, 2014).

The challenges are even greater in Brazil. Despite having some of the largest basins in the world in its vast territory, the country is home to a growing and numerous population. The multiple hydrological realities that we face are expressed by the diverse biomes and ecosystems, multiple water use (e.g., water supply, energy, and agriculture), the social, cultural, and economic diversity at several scales (i.e., local, municipal, regional and national).

The Brazilian Water Resources Association (*Associação Brasileira de Recursos Hídricos* – ABRhidro) is active in the development and dissemination of knowledge for better water resources management in the country. Throughout its history, ABRhidro played important roles in Brazilian society such as stimulating the development of the National Water Resources Management System, created by Law 9433, 1997 (Brasil, 1997). Since its foundation in 1977, ABRhidro routinely organizes the Brazilian Water Resources Symposium (*Simpósio Brasileiro de Recursos Hídrico*s – SBRH) and other thematic and regional events, which brings together researchers and practitioners in the field for discussion and knowledge building. That knowledge has been documented as technical and scientific papers published in national and international conference proceedings (e.g., I SBRH, 1977; XXIII SBRH, 2019; 14º SILUSBA, 2019), books and two scientific journals – Brazilian Journal of Water Resources (*Revista Brasileira de Recursos Hídricos* – RBRH) and Water Management Journal in Latin America (*Revista de Gestão de* Água *da América Latina* – REGA).

The XXIII SBRH was held in Foz do Iguaçu in 2019 and its main theme was WATER CONNECTS (Associação Brasileira de Recursos Hídricos, 2019a). As highlighted by the symposium organizers, "Water connects people and organizations; water connects cultures and peoples; water connects science, technology, and innovation; water connects knowledge with the market; water connects public health, environmental health, quality of life; water connects energy, agribusiness, waterway transport, industry, infrastructure; water connects governments, society, and governance". To enhance the participation of the scientific and technical community in the organization of the symposium, for the first time ABRhidro and XXIII SBRH 2019 opened a call for special sessions organized by the associates, who responded with enthusiasm, proposing several sessions. After a pre-screening, 16 of those special sessions were included in the programme, covering a wide range of topics such as Climate Change, Disasters, Hydrologic and Hydraulic Modeling, Large Scale Hydrology, Education, Water Resources Management.

However, considering the many challenges faced by the water community in Brazil, it is just natural that these efforts for knowledge building are still fragmented, which is also seen in the international hydrology community (e.g., Lall, 2014). Progress in science depends on a strong and active community that enables synthesis activities for "connecting the dots" of knowledge (Sivapalan & Blöschl, 2017). It has been the ABRhidro tradition to publish at the end of each SBRH a letter that is written and revised by its members and that reflects the opinions about relevant current water issues (e.g. Associação Brasileira de Recursos Hídricos, 2019b). The International Association of Hydrological Sciences – IAHS has a long history of community initiatives such as the "Predictions in Ungauged Basins – PUB" (Sivapalan et al., 2003; Hrachowitz et al., 2013), the "Panta Rhei – Everything Flows" (Montanari et al., 2013) and the "Measurements and Observations in the XXI century – MOXXI" (Tauro et al., 2018). Recently, IAHS and other collaborators elaborated in a systematic and collaborative way the "23 Unsolved Problems in Hydrology – UPH" (Blöschl et al., 2019a). We believe that ABRhidro can be aligned with those initiatives, learn from them and start to systematically synthesize the contributions of the SBRH. This systematic synthesis is especially important when we see the growth of the ABRhidro and the SBRH, with a numerous and interdisciplinary community.

Common research topics can increase the critical mass of researchers working on the same questions and therefore accelerate progress in the water resources community (Blöschl et al., 2019a). This type of synthesis work can point out the challenges and questions that will guide community research agendas rather than fragmented individual efforts. Even though institutions such as the Brazilian National Water Agency (*Agência Nacional de* Águas *e Saneamento Básico* – ANA) have been organizing technical reports about the national situation (e.g. Water Resources Situation Report, Agência Nacional de Águas, 2019a; National Water Security Plan, Agência Nacional de Águas, 2019b), the water resources community can further benefit from building a common research agenda.

In this paper we synthesize the special sessions of the XXIII SBRH 2019 in order to understand the major advances and challenges in the water sciences in Brazil. We believe that it can be a stepping stone towards the understanding of the state of the art of water sciences in Brazil, fostering a culture of synthesis in ABRhidro, the building of a common agenda for water resources research, and further encourage the engagement of younger associates.

A detailed overview of advances and debates from XXIII SBRH 2019 is presented in Sections 2 and 3 based on reports from the conveners of the special sessions. Synthesis enabled discussions on the collaborative experiences (Section 4), questions currently being addressed (Section 5), and we conclude with challenges for the Brazilian water community (Section 6).

CALL FOR PAPERS FOR THE XXIII SBRH 2019 SPECIAL SESSIONS

The XXIII SBRH 2019 was the first SBRH to have an open call for special sessions to be organized by the associates of ABRhidro. While there were 13 general themes to compose regular sessions, the scientific committee selected 16 special sessions from the open call, that were then organized by 30 conveners. The sessions accepted full original contributions (maximum of 10 pages) and the presentation of papers previously published in scientific journals. The SBRH committee invited more than 300 reviewers from the ABRhidro community. All submissions were then reviewed by at least one of the selected reviewers. Accepted papers were then published in the proceedings in its complete form or just as abstracts, upon the choice of authors.

Traditionally, papers submitted to the SBRH were classified based on general areas related to water resources. The use of special sessions organized by the community was inspired by the practices adopted in other current conferences (e.g., American Geophysical Union (AGU) Fall Meeting and European Geosciences Union (EGU) General Assembly). The creation of special sessions was well received by the participants (https://eventos.abrh.org.br/xxiiisbrh/pesquisa) and allowed more focus and interactions around a specific interest.

There were 1409 original contributions in the XXIII SBRH 2019, 253 of those were presented in the special sessions (194 oral presentations and 59 posters), while 23 were papers previously published in scientific journals. The number of papers for the different general themes and special sessions was quantified. Figure 1A shows highlights Disasters (14%) and Hydrological studies at regional, national, and continental scales (9%) with a higher number of contributions. When the papers are classified according to the general themes (Figure 1B), the most discussed themes were related to Hydrology (28%), Extreme Hydrological

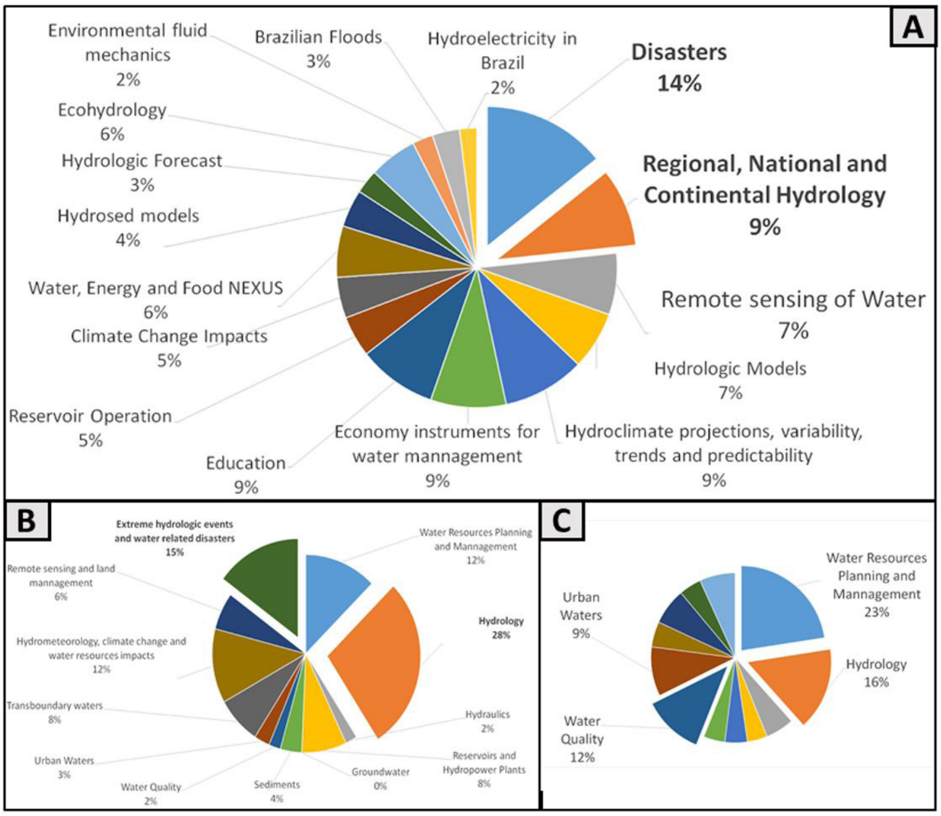

Figure 1. Synthesis of subjects of papers submitted to the XXIII SBRH 2019. Distribution of papers submitted to special sessions (A), according to the general theme (B) and papers submitted to regular sections (C).

Events and Disasters (14%), Hydrometeorology and Climate Change (12%). On the other hand, most papers in the regular sessions were related to Water Resources Management and Planning (23%), Hydrology (16%), and Water Quality (12%). Some topics that were underrepresented in special sessions (Figure 1B) were presented mainly in the regular sessions (Figure 1C), as Water Quality(12%), Urban Waters (9%), Hydraulics (5%) and Groundwater (4%).

Conveners were asked to write a report about the session, including the scientific motivation, the synthesis of the contributions and the debates during the event as well as the perspectives and future challenges (Section 3). The contributions were categorized according to the type of scientific question ("How", "What", "Why") of the 23 UPH (Blöschl et al., 2019a) as discussed in Section 5. Finally, to synthesize and understand the main studied subjects and the network of collaboration of Brazilian water community, the software VOS Viewer (Van Eck & Waltman, 2010) were used to analyze co-occurrence of words in the titles, descriptions of sessions and institutions of the coauthors (Section 4).

UNIQUE FEATURES IN BRAZILIAN WATER RESOURCES AND LESSONS LEARNT

We compiled the unique features of Brazilian Hydrology, the opportunities and lessons learnt from special sessions (Table 1) based on contributions reported by the conveners of each special session as described in detail in next paper sessions.

Brazil is the home of some of the world's largest transboundary basins. The country is characterized by a vast territory that spans over 38 degrees of latitude and a diverse climate that comprises extremely wet and dry conditions. There is a diverse set of landscapes with unique ecosystems composed of dense tropical forests, huge wetlands, savanna and semiarid regions. River basins experience high erosion and sediment transport rates and there are dynamic system changes over large and heterogeneous water bodies with strong diurnal variations in contrast to temperate regions. Brazil is one of the largest food producers, with increasing agricultural irrigated lands that compete with a rich ecosystem and a highly water dependent energy matrix. A large part of Brazilian river network is regulated by a unique hydropower system composed of a massive number of reservoirs with coordinated operation and increasing conflicts with other water uses and flood mitigation. Small and steep basins are often associated with high population density and rapid hydrological disasters due to extreme precipitation rates such as landslides and flash floods. Recent disasters related to dam failures are also of major concern. Therefore, there is an increasing human footprint in Brazilian water resources due to all those economic activities, deforestation, polluted waters, and major river regulation infrastructure. Even though there is a sophisticated National Water Resources Management System, there are still limitations related to the quantity of in situ observations and trained human resources compared to the great challenges related to Brazilian water resources. This unique diversity of natural and human water features brings important challenges and offer a great opportunity for understanding coupled hydrological and societal systems, in line with the Panta Rhei decade of IAHS (Montanari et al., 2013).

Most of the contributions to the special sessions were motivated by the need to develop specific knowledge and tools to tackle some of those challenges recognized by the Brazilian water community. While there are several initiatives both from the education institutions and government agencies, the community would benefit from frameworks for cooperative knowledge building. It is clear that several of the water issues involve a need for comprehensive policies for data collection and availability and also trained human resources and capable institutions to transform data in information and sound decision making. There were innovative tools designed for data scarce regions and the diversity of hydrological characteristics of Brazilian Biomes. Large scale flexible hydrological modeling tools were developed to consider different landscape features such as rivers with complex hydrodynamics and reservoirs. Many new remote sensing applications were used to determine hydrological diversity, ecosystems functioning and human footprint. There is important documented knowledge about the forecast and operation of complex systems of reservoirs. Besides, climate related impact in the water resources and major infrastructure was presented. Regarding the water, energy, and food nexus there has been developed a series of innovative soil and conservation practices based on a forest code, a water policy and a clean energy matrix.

The detailed reports for each session written by its conveners are presented below, including the scientific motivation, the synthesis of the contributions and the debates during the event as well as the perspectives and future challenges.

Hydrological studies at regional, national and continental scales

Issues related to the use and management of water resources and natural hazards surpass the basin borders. Challenges related to extreme floods and droughts, the food-water-energy nexus, climate change, and water conflicts happen at spatial scales ranging from local to large transboundary basins shared by several Brazilian states and South American countries. The concept "One Water Many Souls" highlighted by Lall (2014) is increasingly present and the integrated analyses of all those issues require hydrological studies at a broad range of scales, from local, to national, continental e global ones. That path is now fostered by new data coming from recent advances on hydrological modelling (Bierkens, 2015), remote sensing (McCabe et al., 2017), and improved capabilities for interpretation of large amounts of data. This session brought together scientists, hydrologists, engineers, and water resources stakeholders interested in hydrological studies at regional, national, and continental scales.

From a total of 24 papers, 37% focused on the national and continental scale studies of streamflow regimes and extremes as droughts. Wongchuig et al. (2019) proposed the Hydrological Reanalysis across the 20th century – HRXX aiming at building distributed streamflow records across large basins. The main causes for recent streamflow changes in Brazil were evaluated (e.g. Chagas & Chaffe, 2019b), highlighting a decrease in the North, Cerrado, and Semiarid regions, related to precipitation changes, followed by water use and evapotranspiration. The use of hydrological signatures for classifying Brazilian basins was assessed using in

Table 1. Unique Features of Brazilian Water Resources, Lessons Learnt and Opportunities based on contributions of the XXIII SBRH 2019.

Special Session	Unique Features of Brazilian Water Resources	Lessons Learnt and Opportunities
1 Large Scale Hydrology	Large transboundary basins with diverse climate, landscapes and growing human footprint	Innovative flexible modeling tools for a diverse landscape with rivers with complex hydrodynamics and reservoirs
2 Remote Sensing	Unique ecosystems composed of dense tropical forests, huge wetlands, savannah and semiarid with low density of in situ monitoring	Innovative applications (rivers, bathymetry, water quality, ET and agriculture water uses) with validation and merging satellite datasets to understand hydrological diversity, ecosystems functioning and human footprint
3 Floods in Brazil	Complex flood drivers due to diverse climate and land use variability	There is a spatial coherent pattern of flood change that can be attributed to different flood generating mechanisms that have not been fully explored
4 Disasters	Small and steep basins often associated with high population density and rapid hydrological disasters. High density of hydropower and tailing dams	Disasters reduction relies mainly on a comprehensive policy for data collection and availability
5 Ecohydrology	Diversity of tropical ecosystems that have been underrepresented in global monitoring networks	There is a need for tailor made technology and methods for the contrasting ecosystems and hydrological responses
6 Hydrological Models	The diverse set of catchments are an opportunity for the identification of strengths and weaknesses of hydrological models	While different modeling philosophies are adopted, the community would benefit from a common modeling framework for rigorously testing hydrological models
7 Hydrosedimentological Modeling	Extreme erosion and sediments transport rates at a diverse and data scarce region	Developments on modelling tools focused on the dynamics of tropical regions
8 Hydrological Forecasting	A unique integrated system of large reservoirs spanning a variety of climates and hydrological behaviors	Potential for the development of forecasting techniques for a wide range of temporal and spatial scales, with remote sensing and better field scale real time data paramount to support operational systems.
9 Environmental Fluid Mechanics	Strong diurnal variations in reservoirs in contrast to temperate regions. Large heterogeneous water bodies motivate increasing use of modeling.	While there is a strong focus on field studies, there is an absence of systematic long-term measurements of basic parameters, which are critical for understanding recent land-use, climate change and the impact of large infrastructure
10 Reservoir Operation	Massive number of reservoirs with coordinated operation for hydropower and increasing conflicts with other water uses and flooding.	Unique knowledge from documented experiences of operation of complex systems of reservoirs
11 Hydroelectricity	Electricity generation relies on a continental-scale interconnected hydropower system	The understanding of how diverse and nonstationary river regimes affect hydropower-based systems
12 Hydroclimatic Variability	Diverse responses to teleconnections and varied climates over 38 latitude degrees long territory	Climate and hydrology research questions are shared with 10 countries in two of the largest transboundary basins in the world
13 Impacts of Climate Change	A variety of climate change impacts on water resources, from extreme dry to extreme wet conditions	Projections of a drier north and wetter south of Brazil, but large uncertainties and sensitivity of water resources managements to climate change needs to be accessed
14 Economic Instruments for Water Resources Management	Sophisticated National Water Resources Management System. User engagement, bottom up management and the perception of the value of water are being internalized	Even though the regulatory and institutional framework lacks flexibility and an adaptive management approach, there is enough expertise to drive change
15 Water, Energy and Food Nexus	One of the largest food producer, with a rich ecosystem and water resources, and highly water dependent energy matrix	Development of a series of innovative soil and conservation practices based on a forest code, a water policy and a clean energy matrix
16 Water Resources Education	A wide range of education programs focused on water resources, from PhD, Master, engineering and including Technical Course in Hydrology.	Difficulty of national-level curricula unification due to different regional interests and contrasting infrastructure across educational institutions.

situ gauges (Oliveira & Vrugt, 2019; David et al., 2019a). It was also proposed the use of continental hydrological modelling for estimating South American reference streamflows (Ribeiro et al., 2019) and a WebGIS system for sharing continental scale model streamflow (Medeiros et al., 2019).

Part of the contributions (30%) focused on hydrologic-hydrodynamic predictions at large scale through the development or use of models and software (e.g. MGB model). Fleischmann et al. (2019a) multiscale analyses show that improving current regional/continental scale hydrodynamic predictions to a locally relevant level depends on enhancing bathymetry information among other factors. In this sense, some works proposed methods for the analyses of in situ bathymetric information and also including remote sensing imagery and altimetry (Souza et al., 2019a; Brêda et al., 2019a; Buffon et al., 2019, Vargas et al., 2019). Other modelling applications include the use of MGB for mapping Brazilian rivers impacted by large reservoirs (Passaia et al., 2019b) and dam break analyses of cascading reservoirs (Alves et al., 2019b). There were also papers related to studies of coupled basin-river-lake systems, precipitation datasets, and regional extreme rainfall analyses at the regional scale.

The new opportunities and questions raised during the event include: the use of model outputs and hydrological reanalysis for mapping continental scale hydrological regimes, variability and changes; comparing reported past hydrological variability and projections of future climate change; uses of national level hydrological estimates for water resources management; development of national level monitoring and decision making systems for institutions as Brazilian National Water Agency (ANA); enhancing continental scale hydrodynamic predictions through improved bathymetry; hydroecological impacts of reservoirs at the national scale; continental scale databases of potential impacts of dam breaks. The themes subject to the call for this session that were not assessed were: characterization of hydrological processes from macroclimates and biomes; quantification of water uses at large scale; water resources management, past, present, and future scenarios of water conflicts at large scales.

Remote sensing of water: perspectives from a new information era

Recent advances in Remote Sensing and Earth System Observation is providing improved monitoring of the water cycle, especially for regions with limited in situ measurements. The development of multiple measurement platforms and sensors, starting at the end of XX century, allowed the estimation of several hydrological processes such as precipitation, evapotranspiration, soil moisture, terrestrial water storage, surface water hydrodynamics, and water quality, making remote sensing a preeminent field in hydrology (Lettenmaier et al., 2015; McCabe et al., 2017). A change of paradigm is taking place, from the ungauged basin towards all global rivers and basins having at least one kind of measurement or estimation. The new opportunities from remote sensing bring new challenges to the water resources community, and it is necessary to investigate several issues as: new applications, methods to use and improve large datasets and account for its uncertainties, improved algorithms for estimation of water cycle components, etc. This session brought together scientists, hydrologists, engineers, and professionals interested in the use of remote sensing for the water cycle observation and its applications on water resources management.

The session received 18 papers. Part of it focused on the (i) surface waters, as Andrade et al. (2019) that presented methods for estimation of lake bathymetry using flood frequency from satellite imagery and Martins et al. (2019a) that focused on river profiles from radar altimetry. Avila et al. (2019), Munar et al. (2019), and Moura et al. (2019) presented promising methods for studying water temperature and energy balance of subtropical and tropical lakes using thermal remote sensing and hydrodynamic modeling. Other contributions focused on (ii) hydrometeorological processes, as evapotranspiration estimates for large scale monitoring water use on agriculture (Kayser et al., 2019), understanding natural patterns in the tropics (Moreira & Ruhoff, 2019), and land use classification and change (Santos et al., 2019b; Andrade et al., 2019a). There was also drought monitoring based on remotely sensed vegetation and soil moisture indexes (Nagel & Terra, 2019) and the validation of multiple remote sensing products based on hydrological modelling (Ferreira et al., 2019). The remote sensing of (iii) water quality of rivers, lakes and estuaries was also assessed. It included the development of semiempirical models for sediments and chlorophyll concentration retrieval based on multi and hyperspectral reflectance measurements from in situ, satellites and drone imagery (Lins et al., 2019; Alves et al., 2019a; Fraga et al., 2019b; Caballero et al., 2019), and understanding water quality processes related to the Doce River dam break (Silva et al., 2019b) and the Lagoa dos Patos estuary (Bárbara Neto et al., 2019).

The contributions and discussions from this session showed the potential of remote sensing for monitoring Brazilian water resources, from small areas to continental scale. Opportunities include the remote sensing of other water cycle components, such as groundwater, floods, and river discharge. There is still the challenge of moving from the experimental calibration and validation studies on the retrieval of hydrological variables towards applications focused on the understanding of natural systems, environmental changes, and water resources management.

Floods in Brazil: processes, risk analysis and uncertainty estimation

Life and monetary losses related to floods have been increasing all over the world, Brazil being the second with the greatest flood loss potential among all the emergent countries (United Nations Office for Disaster Risk Reduction, 2015). Many of the mechanisms that drive and control floods are still not completely understood. Moreover, many of those flood generating mechanisms have been changing as a result of the complex interactions between climate, land use change, and river systems (Blöschl et al., 2017, 2019b). The objective of this special session was to analyze the main processes that control floods in Brazil, including their spatial and temporal patterns across different scales. This session is related to questions 9 and 10 about the detection, attribution, and change in floods of the 23 Unsolved Problems in Hydrology (Blöschl et al., 2019a).

The papers in the session dealt with the topics of spatial patterns, classification and attribution of floods, frequency analysis, trends, and uncertainty estimation in annual maxima. Considering the importance of the identification of homogenous regions for regional frequency flood analysis, Cassalho et al. (2019) showed that the combination of several classification techniques increases the confidence in the annual maxima estimates. Correa & Silva (2019) showed that for the 2014 Madeira River flood the increment of flow between two reservoirs of hydropower plants was negligible in relation to the magnitude of the upstream flood. In the case of the Paraguai River basin, Santos & Lima (2019) classified the flood producing storms and showed that a mixed distribution was useful for flood frequency analysis. A comparison of non-stationary and stationary frequency models for 275 gauge stations in Brazil showed a clear spatial pattern for the stations that had significant trends in annual maximum series - AMS (Bartiko et al., 2019). Regarding the Paraná River basin, Chan et al. (2019) showed that the majority of the AMS from hydropower reservoirs inflows were stationary.

In this session, there were several discussions concerning the technical and operational aspects of flood prevention. In the Madeira Basin case, it was highlighted the importance of international collaboration with upstream countries (i.e. Peru and Bolivia) for improving automated monitoring and flood warning systems. Moreover, it was greatly emphasized the need for continuous automated monitoring and the measurement of events of great magnitude. Another challenge raised by the community is the need for scientific understanding of the main flood generating mechanisms in Brazil. We still need to improve the understanding of the hydroclimatology and drivers of regional floods and on flood change attribution.

Disasters

The study of disasters is key for water security considering the increasing number and impacts of natural and technological water-related hazards (United Nations Educational, Scientific and Cultural Organization, 2019). Floods are the disasters that affected the largest number of people in the XXI century (on average 90 million people per year, Centre for Research on the Epidemiology of Disasters, 2019). Landslides and long droughts are the other most impactful hazards in Brazil (Universidade Federal de Santa Catarina, 2013). Moreover, technological disasters are increasingly frequent and deadly in Brazil, with recent dam breaks affecting hundreds of lives and bringing strong concerns in people living along river valleys downstream from dams. Those issues highlight the need for improved understanding of the driving factors causing those disasters and the relation between hazard and population vulnerability. The Disasters session had a large attendance, with contributions that were categorized into: (i) landslides; (ii) floods; (iii) dam breaks; (iv) droughts; and (v) disasters and society.

There is a large incidence of landslides along the Brazilian coast (Fernandes et al., 2001; Petley, 2010; Sepúlveda & Petley, 2015), where shallow translational landslides with debris flow are the most common and deadly combination. Paul et al. (2019) compared models used for predicting translational landslides in space and time. Debris flows that are similar to free surface and rapid flow are usually represented using hydrodynamic models, as in Villela & Kobiyama (2019). Salvador & Michel (2019) and Cardozo & Michel (2019) proposed new empirical methods for mapping areas susceptible to debris flows. The connectivity concept (Merriam, 1984) is increasingly used in water resources (Wohl, 2017; Zingaro et al., 2019; López-Vicente & Bem-Salem, 2019), however, this concept is still rarely applied in Brazilian studies, mainly those ones related to sediments. (Zanandrea et al., 2020). Connectivity has also been useful for understanding the relationship between landslides and sediment yield (Zanandrea et al., 2019) and hazards (Kobiyama et al., 2019), as presented at this symposium.

Floods are the main natural hazard impacting highly populated regions of Brazil. Several contributions focused on flood mapping using terrain descriptors (Abatti et al., 2019; Monte et al., 2019; Vasconcellos & Kobiyama, 2019), artificial neural networks (Oliveira et al., 2019a) and hydrodynamic models (Monte et al., 2019). Rapid floods are the main natural hazard occurring over headwater in Brazilian mountainous regions. Collischonn & Kobiyama (2019a, 2019b, 2019c) described the "cabeça d'água" phenomena, it is a kind of a rapid flood that affects tourists and swimmers at rivers, but it was not documented in the scientific literature although it is frequently reported in newspapers. Guirro & Michel (2019) showed how rapid floods can be caused by the break of dams formed by sediment deposition from landslides over river valleys.

The recent failure of dams from Vale S.A. company at Mariana and Brumadinho cities and their impacts highlighted the hazards related to dam breaks over Brazilian territory. Tschiedel et al. (2019) concluded from statistical analyses that dam breaks can become more frequent. Emergency plans still need to be implemented for most of the Brazilian dams to attend the National Dams Security Policy, although there is still no consensus on methods. For example, Chagas et al. (2019) and Matos & Eleutério (2019) studied methods to predict flooding extent due to dam breaks, while environmental issues as water quality and vegetation recovery were reported by Vasconcellos & Kobiyama (2019) and Venzon et al. (2019).

Recent persistent and large scale droughts also impacted Brazil. Drought indexes were evaluated by Tomasella & Cunha (2019). While Nauditt et al. (2019) quantified vulnerability and risks related to droughts, Peixinho (2019) proposes a strategic plan of water resources to adapt to droughts over the semi-arid region.

As disasters develop from interrelated physical and social aspects, traditional approaches seek to understand how disasters impact society. Silva & Eleutério (2019) and Matos & Eleutério (2019) used tools to evaluate life losses related to water hazards. On the other hand, as society also impacts the occurrence of hazards, the interdependence of physical and social aspects is currently approached as Socio-Hydrology by the water resources community, as discussed by Vanelli & Kobiyama (2019).

A large number of contributions to this session show the active involvement of ABRhidro community in the disaster theme. Several papers presented and tested methodologies to map areas subject to disasters, its hazards, vulnerabilities, and risks, contributing to the National Policy for Protection and Civil Defense (12.608). There is still the need for more research focused on field measurements, monitoring systems, understanding processes causing disasters in small scale headwater systems, where 90% of Brazilian disasters occur according to the Center for Monitoring and Early Warnings of Natural Disasters (*Centro Nacional de Monitoramento e Alertas de Desastres Naturais* – CEMADEN) and current technologies are still not capable of providing accurate predictions.

Ecohydrology: advances, perspectives and challenges about the interactions between water and Brazilian ecosystems

In the ecohydrology session, we discussed the interactions that occur between different Brazilian ecosystems and the hydrological cycle. We received contributions that presented research outcomes from terrestrial ecosystems, evidencing the relationship between the ecoregions and the hydrological processes, or focused on physical, ecological, biological, biogeochemical, geomorphological, mathematical and methodological aspects related to field studies, including monitoring and modeling techniques. Additionally, initiatives that investigated the relationship between the ecosystem and water resources management were also included in the program.

Catchment and hillslope hydrology were the core of the discussions along the ecohydrology session based on existing experiments (Sá et al., 2016; Anache et al., 2019). We expected to receive contributions from all Brazilians biomes: Amazon, Caatinga, Cerrado, Atlantic Forest, Pantanal, and Pampa. However, representatives of three biomes presented contributions along the 2019 session: Cerrado, Atlantic Forest, and Pampa. Thus, a misrepresentation of all biomes reflected the lack of an equal distribution of research initiatives in the country. Moreover, Cerrado and Atlantic Forest dominated the discussions and contributions in the number of presented studies. The contributions were grouped in three main research topics: (i) catchment and hillslope physical hydrology; (ii) spatialized water cycle components assessments; and (iii) water resources management in the context of specific ecosystems.

The debate mainly focused on methods and sampling criteria of rainfall interception by native arboreous vegetation and hillslope runoff (Sá et al., 2019; Santos et al., 2019a), and aspects related to spatially distributed evapotranspiration estimation methods (Fontana & Collischonn, 2019). Concerning the 23 UPH (Blöschl et al., 2019a), the ecohydrology session moved towards helping through several problems, and we may highlight three questions: 4, 16, and 22. Lastly, it was observed that important ecological regions in Brazil were not represented in this session, such as Amazon rainforests and Pantanal wetlands. Thus, we expected to gain attention from the Brazilian water community in order to enhance the discussion in the subject by contrasting the outcomes from our wide and diverse group of Brazilian ecosystems.

Hydrological models as hypothesis of catchment functioning

Hydrological models are tools that allow different hypotheses of catchment functioning to be tested. One aim of hydrological modeling is to identify the major controls that drive catchment response, which may enable the transfer of knowledge in time and in space. In order to correctly identify the dominant process through hydrological modeling, we need to assure that good results are being obtained for the right reasons ("Getting the right answers for the right reasons" – Kirchner, 2006). Hydrological models should be adequately calibrated and rigorously tested, avoiding errors to be compensated in model calibration and assuring that the model formulations represent the process they intend to represent (Hrachowitz & Clark, 2017). Moreover, it is important that uncertainties associated with model results are quantified, recognizing the limitations of the derived conclusions. Rigorous model calibration and evaluation have the potential to reduce type I errors – failure to reject "bad" models – while the consideration of uncertainties may reduce type II errors – falsely reject a "good" model (Hrachowitz & Clark, 2017). The aim of this session was to bring together studies about hydrological modeling in Brazil in order to promote discussion on ways to improve the fidelity of hydrological models.

The sixteen papers presented in this session included a variety of approaches relative to: (i) the type of model used – from concentrated conceptual models to semi-distributed models; (ii) the calibration method – manual and automatic, mono-objective and multi-objective, with and without consideration of uncertainties associated with model results; (iii) the spatial scale – from plot scale to large basins; and (iv) the modeling objective – improvement of the understanding of dominant processes, model refinement through the comparison of different formulations, comparison between models, comparison between calibration methods, improvement of model realism, and simulation of future scenarios.

It was verified that a common approach to hydrological modeling is still lacking. The choice made at each step of the modeling process (i.e., model selection, calibration method, evaluation of the calibrated model, uncertainty quantification) is subjective and rarely justified. Evaluation of model complexity was rarely discussed. Föeger et al. (2019b) showed that formulations with different levels of complexity resulted in similar model performance. That result highlights the importance of evaluating the degree of model complexity needed to characterize catchment processes and response. Uncertainty analysis was addressed in a few studies. David et al. (2019b) verified that many models result in similar performance when the uncertainties associated with model simulations are considered.

The main challenge raised by the community during the session was "how to obtain the right results for the right reasons". As an alternative to the "traditional modeling", in which hydrological models are calibrated and evaluated using only discharge data, it was suggested that other fluxes should be verified. This would involve: (i) the use of different types of data to check the functioning of the model; (ii) model calibration to be performed with variables other than discharge, even if this causes a reduction in model performance; and (iii) the evaluation of model performance using different metrics. In the study of Meyer et al. (2019), the hydrological model MGB was calibrated with discharge and remote sensing observations, pointing a way forward in that direction. The use of nonsystematic data, as in Vanelli et al. (2019), may be helpful in order to complement and evaluate systematic data. Progress in hydrological modeling can also be achieved with the testing of alternative formulations (i.e., hypotheses) of catchment functioning. Other challenges for future studies include the adaptation of hydrological models to changing conditions and the attribution of uncertainty to its different sources. These are listed as the 23 Unsolved Problems in Hydrology (Blöschl et al., 2019a) and were underrepresented by the papers in this session.

Hydrosedimentological modeling

Assessing erosion and sediment flows is important for several applications, such as understanding impacts on ecological functioning and the biogeochemical cycle (Galy et al., 2015; Naipal et al., 2018), evaluation of land use and land cover changes (Oliveira et al., 2015), variations related to climate change (Bussi et al., 2016), silting of watercourses and reservoirs (Sumi & Hirose, 2009; Mamede et al., 2018), difficulties in water treatment, and navigation dredging necessities (Best, 2019). Computational mathematical techniques and models complement the monitoring strategies, allowing the best possible use of the primary data, which are generally very scarce in hydrosedimentology (Pandey et al., 2016). A hydrosedimentological model calibrated for a basin allows one to make inferences about the past, the present, and the future of its sediments. For this reason, this session aimed to bring together those interested in the theme of development and application of hydrosedimentological mathematical models.

In total, eleven (11) technical papers were presented in the session, three of those papers were already published in scientific journals. The papers were related to model development and application as well as empirical methodologies for estimating sediment discharge. Colman et al. (2018) evaluated soil loss and sediment input using the sediment delivery ratio (SDR) approach to estimate sediment yield in tropical basins. While Föeger et al. (2019a) developed a hydrosedimentological model for application on large scale data-scarce areas, Palu & Julien (2019) used modeling to understand the transport behavior of the hyper-concentrated sediment plume of the Fundão/MG tailings dam break along the Doce River. Other papers treated data evaluation and information production for use in hydrosedimentological modeling (Fagundes & Bravo, 2019; Rossoni & Fan, 2019a, 2019b). Fagundes & Bravo (2019) evaluated the calibration of a sediment model in data-scarce conditions and concluded that the amount of measurements affects the improvement of the model results, but the values of performance metrics are less susceptible to the amount of information.

As a way of improving the information derived from data of sediment gauging stations, Oliveira et al. (2019d) used Artificial Neural Networks to identify which variables have the greatest impact on the process of calculating solid discharge in rivers. Also, Oliveira et al. (2018) demonstrated the potential of using synthetic rainfall series to estimate the rainfall erosivity index, a parameter considered in soil erosion models such as Universal Soil Loss Equation – USLE and Revised Universal Soil Loss Equation – RUSLE. Granadier & Rauen (2019) analyzed sediment transport and dune impacts on rivers. For environments where the dominant erosive process is the landslides, Paixão & Kobiyama (2019) evaluated the use of the Egiazaroff equation for non-uniform sediment flow as a way to better estimate erosion in mountainous regions.

As a result of this session, it is clear that the national scientific community has advanced and is aligned with the international community in the use of models to understand the dynamics of sediments in different scales. There is a lot of effort in the development of techniques and models for data-scarce regions and it was highlighted that the efficiency of the models is directly related to the availability of data. Part of the difficulty in validating models is due to the meager measurements of suspended sediments. Uncertainties are especially high in flood periods with sediment usually being estimated from the extrapolation of sediments rating curves to values beyond those observed. It was discussed that the field data sampling programs are generally inadequate in determining long-term sediment loads and that the country needs to invest more in monitoring. In addition, Brazil does not have a policy for measuring bedload in rivers. On the other hand, in data-scarce basins, the use of models associated with different sources of information in addition to field monitoring, especially those derived from remote sensing, has made great progress in national and international scientific circles. Finally, one of the greatest challenges is to expand model applications beyond the usual quantification of sediment flow and try to understand how those processes of production and transport occur.

Hydrological forecasting

Hydrological forecasting is of paramount importance for water resources management and planning. Typical applications are related to early warning systems, reservoir operation, flood control, water supply, and navigation. Given the continental dimensions of Brazil, its large dependence on water for energy production and vulnerability to extreme hydrometeorological events, there is an increasing need to develop hydrological forecasting techniques considering multiple temporal (e.g. short- to seasonal ranges) and spatial scales (from small basins to the entire country) (Fan et al., 2016; Oliveira & Lima, 2016; Casagrande et al., 2017; Quedi & Fan, 2020; Siqueira et al., 2020).

Seven (7) technical papers related to hydrological forecasting were presented in this session. Gama et al. (2019) focused on developing tools to facilitate the use of data assimilation and showed its positive impacts on forecast accuracy. Silva et al. (2019f) demonstrated that merging real-time satellite information with rainfall data from in situ gauges leads to improvements in streamflow forecast performance. Five (5) studies also included predictions from atmospheric models as input to the hydrological models, particularly from the regional WRF (Weather Research Forecasting) for short- to medium ranges and from the global ECMWF (European Center for Medium-Range Weather Forecasts) for medium- to subseasonal ranges. Giacomelli et al. (2019) showed that such an approach has been adopted for an early warning system developed for the Rio Grande do Sul state, which is currently issuing forecasting reports with lead times up to 7 days in advance. Special attention was given to consider uncertainty in hydrological forecasts by making use of ensembles, showing that the Brazilian community is increasingly embracing this type of technique that was only presented experimentally at the XX SBRH of 2013 (Fan et al., 2013). Quedi & Fan (2019) and Cunningham et al. (2019) evaluated ensemble hydrological forecasts with lead times up to 6–7 weeks, suggesting potential benefits in the context of energy production and prediction of extreme wet spells. Scortegagna et al. (2019) presented an operational, multimodel forecasting system for lead times up to 7 days that indicates the probability of discharges lying below a critical threshold, while Siqueira et al. (2019) showed that statistical postprocessing could improve the reliability and skill of medium-range (up to 15 days ahead), raw ensemble hydrological forecasts in several locations across the South American continent.

Among the main limitations reported are the low density and quality of real-time hydrometeorological data. Current recommendations for the minimum number of telemetric gauges for hydroelectric projects (joint Resolution 03/2010, Brasil, 2010) are insufficient for the proper operation of forecasting systems. Regions with few hydroelectric plants, as in the South of Rio Grande do Sul State, have a more marked lack of telemetric data for hydrological forecasting. In this context, satellite precipitation estimates, which are currently available in near real-time, can be fundamental to overcome the low coverage of telemetric gauges and have the potential to be used operationally (Fan et al., 2016). There were also recommendations on studying the potential benefits of other sources of remote sensing data (e.g. radar altimetry, soil moisture, among others) for assimilation in hydrological models (e.g. large spatial scales), since these data have global coverage and can be obtained free of charge. Finally, investigating strategies on how to communicate probabilistic hydrological forecasts to end users was highlighted as a key research topic to leverage ensemble forecasting practices in Brazil.

Environmental fluid mechanics: monitoring and modeling of reservoirs and coastal systems, environmental hydraulics, and physical limnology

Focusing on the Symposium theme, Water Connects, this session demonstrated how water connects the lithosphere, atmosphere, and biosphere, in freshwater, brackish water, and seawater systems, coupling indissociable physical, chemical, and biological processes at microscopic and macroscopic scales. This session aimed to connect research that involves monitoring and modeling of aquatic systems under a quantitative perspective, emphasizing how physical processes interact with the dynamics of chemical and biological quantities. The importance of those topics was shown in Winton et al. (2019), who highlighted the thermal stratification in tropical reservoirs and its relation to water quality and sediment processes.

There were 13 papers selected. Those were related to one-dimensional models applied to water supply reservoir management (Soares et al., 2019; Sales et al., 2019), in-situ measurements of sedimentation in reservoirs (Ono et al., 2019), internal waves during thermal stratification (Bueno & Bleninger, 2019), hydrodynamics and water quality in reservoirs (Nocko & Cancelli, 2019), and semi-arid reservoir limnology and cyanobacteria blooms (Wiegand et al., 2019). Furthermore, the determination of lake forcings by river temperature variations were presented by Colombo & Mannich (2019) estimating stream temperature computed from air temperature. Coastal waters were addressed by studies in estuaries on the hydrodynamic effects on water quality (Andrade et al., 2019b), dredging consequences on the salt wedge in harbor regions (Rezende & Bleninger, 2019), and sediment transport analysis for beaches with coastal structures (Silva et al., 2019e).

The lively discussions showed that environmental fluid mechanics application in Brazil is still diffuse, even though there is very strong knowledge and high demand for such studies. The reasons for that were suspected of being a highly interdisciplinary field requiring more interaction and collaboration. Integrated approaches are thus seen to offer promising comprehension. The fast growth of infrastructure in coastal areas and increasing pressure on water supply and hydropower reservoirs made modeling approaches the tool for predicting hydrodynamic effects and water quality changes. However, those models are only as good as their input data. Unfortunately, it has been observed that the presented papers are the few good examples that had good data with model applications. It was clearly shown that systematic measurements of basic parameters in stratified flows, such as temperature and salinity profiles, especially using automatic sensors are a large gap in Brazil.

The overall paper quality was very good, and the challenges suggested a better integration of researchers in Brazil with ABRhidro as a platform for further collaborations - Water Connects! A first positive result from this meeting was the creation of a working group which is an embryo of this idea, where students and their supervisors currently from the Federal University of Paraná (*Universidade Federal do Paraná* – UFPR), the University of São Paulo (*Universidade de São Paulo* –USP), the Federal University of Minas Gerais (*Universidade Federal de Minas Gerais* – UFMG), the University of Brasilia (*Universidade de Brasília* – UnB), and the State University of Maringá (*Universidade Estadual de Maringá* – UEM) started with a monthly short presentation series.

Operation of reservoirs and systems of reservoirs

Water resources availability is increasingly controlled by reservoirs and transpositions. The operation of those systems offers complex challenges due to increased conflicts related to water use and operational restrictions as a result of human occupation close to rivers and reservoirs. The session Operation of reservoirs and systems of reservoirs received 23 papers (12 orals, 11 posters). The contributions from this session brought analyses, proof of concept, and case studies providing the exchange of technical and practical experiences from scientists and engineers working in the reservoir operation field.

Part of the contributions focused on large scale systems and water supply reservoirs in the northeast region. White et al. (2018) presented lessons from the development of a decision-making system of water management for the Pernambuco state, including reservoir operation, flood forecast, and scenario analyses on a web system. Gomes et al. (2019a) showed the optimization of Cruzeta water supply reservoir in Piancó-Piranhas-Açu rivers and how the operational rules can decrease the failure rate of priority water demands. Souza et al. (2019b) assessed the project for the integration of the São Francisco River in the context of the transposition system and recommended improved rational management accounting for local hydrological states, expected inflows and pumping costs. Passaia et al. (2019a) performed an exploratory analysis to document the behavior patterns of many Brazilian hydropower reservoirs (*Sistema Interligado Nacional* – SIN) using data from the SAR system from ANA. While Fleischmann et al. (2019b) developed and evaluated a modelling framework for the Paraná basin using the MBG model, accounting for hydrology, hydrodynamics, and 54 reservoirs with different operational rules, that simulate flow attenuation observed at in situ gauges. Monteiro et al. (2019) showed from the Jequitinhonha river case study how evapotranspiration is an important issue that has to be accounted for in the design of regulation reservoirs.

Several other contributions focused on the operation of hydropower reservoirs. Araujo et al. (2019) showed methods for the hydraulic operation of cascading reservoirs of the Iguaçu River. As this operation is performed by several different actors, it was highlighted the importance of coordinated and integrated actions. Freitas et al. (2019) presented the case study of the Mauá hydropower plant at Tibagi River, including its hydraulic operation methods, field information and revisions of the flood spillway. Khenayfis et al. (2019) proposed a new method for the estimation of reservoir outflows based on downstream water levels. Such information can enhance the performance of optimization models and hydraulic operation. Werlang et al. (2019) presented a new estimation procedure for the Itaipu reservoir inflows, named "*Afluência Consistida*". It used the equivalent reservoir water level and it is less sensitive to external influences and water level observations. Urzulin et al. (2019) presented revisions of flood flow restrictions of the lower Paraná river from Jupiá to Porto Primavera hydropower plants. As a result, operational restrictions could be revised, increasing reservoir storage without damages to the riverine population. Subira & Bueno (2019) demonstrated improvements in the operation of a water supply system, with lower operational costs through the automated flow valves of a Sabesp (*Companhia de Saneamento Básico do Estado de São Paulo*) dam.

The present and the future of hydroelectricity in Brazil

The expansion of hydroelectricity in Brazil is considerably reducing, mainly because of environmental constraints and scarcity of places for the construction of new plants (Empresa de Pesquisa Energética, 2019). Even so, hydroelectric generation currently accounts for more than 60% of the country's electricity generation capacity (Agência Nacional de Energia Elétrica, 2020). This dependence has been evident in recent years with the strong water crisis experienced in many parts of the territory. On the other hand, several Brazilian rivers show increasing long-term trends in its streamflows, as a result of the statistical nonstationary nature of such series.

The papers presented in this special session explored the mentioned issues in different ways. Treistman et al. (2019) showed that the El Niño - Southern Oscillation (ENSO) climatic phenomenon influences the natural flow regime of hydroelectric plants operating in the North and South regions of Brazil. Massing et al. (2019) analyzed series resulting from operation of reservoirs, concluding that the plants in the Northeast and part of the Southeast show decreasing trends in their streamflows. The reverse effect was identified in plants located in the South, part of the Midwest, and the remainder of the Southeast region. In the next paper, Detzel et al. (2019) presented one of the consequences of these nonstationarities. The author exhibited evidence of a change in the reservoirs' critical inflow period from the 1950s to the 2010s in plants operating in the Southeast and Northeast. Subsequently, the presentations that completed the session focused on case studies of hydroelectric plants that operate on the Iguaçu River (Paraná State). Bueno et al. (2019) showed the energy gain that the Baixo Iguaçu run-of-the-river plant would have if it was operated as a regularization reservoir. In turn, Santos et al. (2019c) analyzed the insertion of pumped-storage hydroelectric plants in the Brazilian electrical system, showing a potential application in the Salto Santiago plant.

In addition to specific questions about the techniques shown by all the authors, the audience discussed general questions about the problems of hydroelectricity in Brazil. The presentations focused on issues that are not currently considered in the operation of the system, which motivated questions on how to make the presented proposals viable. Moreover, the audience also discussed prospects for the system. They commented on issues such as energy storage, repowering of plants, energy consumption, uncertainty, and short-term solutions for already existing (yet unsolved) problems. These issues will guide the future of hydroelectricity in Brazil.

Variability, trends and hydroclimatic predictability/ use of climate projections in hydrological impact studies and climate services

Extreme hydrometeorological events require adaptation for increasing resilience in vulnerable regions. Adaptation involves studying climate variability to improve hydrometeorological predictability, ensuring more accurate flood and drought alerts, information for risk mapping, disaster response and reconstruction management, planning, and rational use of water resources. It also requires changes in attitude, collaboration, data exchange, information, and knowledge sharing by research institutions, public administration, the private sector, communities, and individuals to increase the resilience of human settlements (World Meteorological Organization, 2016). This session aimed to prospect scientific knowledge on hydroclimatic variability and ongoing changes, predictability, use of climate projections, and application of climate services in the context of water resources. The conference papers were motivated by: improving the understanding of processes associated with extreme events (floods and storms) and their predictability, generating reliable information to the adequate management of water resources, especially in supply, agriculture, and hydroelectric generation.

The main scientific questions answered include: identification of the relations between precipitation (excess or lack) and oceanic-climatic indices (Vásquez et al., 2018); identification of long memory process (persistence) and seasonality in the inflow rates to the Descoberto reservoir located in Distrito Federal (Giacomazzo et al., 2019); verification of the skill of two European models for sub-seasonal precipitation forecasts in the state of Ceará (Pereira et al., 2019); identification of the influence of convective activity associated with the Madden-Julian Oscillation (MJO) over tropical South America (SA) and the Atlantic on the summer monsoon anomalies in Southeast Africa (SAF), by teleconnection between SA and SAF (Silvério & Grimm, 2019) complemented by influence of La Niña (Fernandes et al., 2019); improvement in the results of the CMIP5 (Coupled Model Intercomparison Project 5) climate models for the South of Brazil with the Quantile Mapping (QM) bias correction technique (Pereima et al., 2019); use of instability indices for predicting extreme rainfall in urban regions (Silva et al., 2019h); identification of trends in precipitation and streamflow decrease in Tucuruí and increase in Itaipu (Silva et al., 2019g); performance evaluation of the regional model Eta-CPTEC in the sub-seasonal scale for the São Francisco River basin (Silva et al., 2019d); besides studies on trends, both at local (Silva et al., 2019a, 2019g; Juliani et al., 2019) and regional scale (Silva et al., 2019h; Chagas & Chaffe, 2019a; Vásquez et al., 2018). The study by Borges et al. (2019a) mapped 51 institutions that provide climate information for water resources in Brazil.

From the discussions, it stands out the necessity to increase the seasonal and sub-seasonal predictive capacity, given its applicability to decision-making in reservoir management, agriculture, and other economic sectors, including the planning of individual activities of the common citizen. It is necessary to use as many models as possible for the same region and purpose, considering that different models may be more or less suitable for different regions, time horizons and climate indices. At the same time, it is necessary to improve the physical understanding of the relationship between sea surface temperature and precipitation in inducing variations in circulation in various regions, and other climate indices with precipitation. Additionally, it is essential to think about the operation of reservoirs in the face of future scenarios of precipitation and streamflow. For trend analyses, the next step is to identify the causes of non-stationarity. Another relevant point is the translation of scientific information into effective actions that allow greater resilience to climate hazards. Following the central theme of the XXIII SBRH "Water Connects", it is recommended the establishment of a community of Climate Services for the exchange of data, information, and experiences.

Impacts of climate change on water resources in Brazil

Climate change threatens society by increasing water demand, reducing water supply by increasing evaporation and changing rainfall patterns, and increasing the frequency and intensity of extreme events. Although globally the impact of climate change on water resources is undeniable, we still need to better understand how these changes occur at the regional and local levels (Intergovernmental Panel on Climate Change, 2014). In Brazil, the negative consequences for public supply, agriculture, and hydroelectric production are already a reality (Agência Nacional de Águas, 2019a) and may intensify in the future (Borges & Chaffe, 2019). Under this challenge, this session brings scientific evidence on changes in observed streamflow and water demand, as well as estimates of future changes in the hydrological regime and extreme events, and also invites approaches to enhance the adaptation of water resources in Brazil.

The session comprised twelve studies. Gomes et al. (2019b) suggested that there is sufficient evidence on non-stationarity of streamflows in Brazil, and the application of this type of analysis is strongly recommended for water resources management. Amorim et al. (2019) identified a functional correlation between atmospheric variables and the thermal response of a lake, allowing faster forecasts for reservoir management. Barbosa & Becker (2019) found that, in periods of extreme rainfall and droughts, there is an intensification of eutrophication in reservoirs located in a semiarid region. Domingues & Rocha (2019) identified a significant sensitivity of the streamflow of the Jaguari basin to the warming and drying of the air. In terms of scenarios of climate change impacts, Almagro et al. (2017) suggested that north-eastern and southern Brazil are likely to be affected by rainfall erosivity. Tavares et al. (2019) estimated that an increase of 1 °C and 2 °C in the air temperature resulted in an increase of 0.73 °C and 1.48 °C in the temperature of the Mangueira-RS lagoon. Lima & Arteaga (2019) showed an increase in the maximum and minimum magnitudes of the South American Monsoon indices for both scenarios RCP4.5 and RCP8.5, especially in the summer, indicating an intensification in the patterns of precipitation. Billerbeck & Mello Júnior (2019) identified variations in the average monthly rainfall in the Piracicaba River basin for the future period from 2019 to 2099. Martins et al. (2019b) estimated losses of around 30% in corn productivity in Northeast Brazil under the RCP4.5 and RCP8.5 scenarios. Through a large-scale hydrological model forced by 25 climate models, Brêda et al. (2019b) projected a significant decrease in the runoff in the southeast Amazon, Tocantins, Parnaíba, and São Francisco hydrographic regions. These results corroborate with Borges et al. (2019b), who developed a tool that allows access and visualization of the synthesis of dozens of studies that assessed the impacts of climate change on the water resources in Brazil. Finally, Buchir et al. (2019) demonstrate the importance of including aspects of governance in the development of climate vulnerability indices, and that systems with sound governance are more resilient to climate hazards.

The session promoted discussions about the importance of analyzing the sensitivity of water systems to climate variability. Future scenarios should be compared with ongoing changes to find regions where changes are more (un)certain. In addition, the importance of using a significant number of climate models was highlighted. Finally, participants discussed how impact scenarios can be incorporated into climate vulnerability indices to support more robust adaptation measures.

Economic instruments for water management, from theory to practice

This session summarizes research and technical reports exploring theoretical aspects and practical examples of water economics, allocation and value, including economic water management instruments. This included water charges, water markets, negotiated allocation and hidro-economic methods (Vichete & Mello Júnior, 2019), financial sustainability (Silva et al., 2019c), tradeoff analysis and economic water opportunity costs in Brazil (Belladona et al., 2019; Riediger & Marques, 2019).

There were notable advances in negotiated water allocation instruments, as in the example in Oliveira et al. (2019b) for the Rio Preto basin, which demonstrated a stakeholder participatory process involving negotiated alternating irrigation schedules under a drought event. According to Oliveira et al. (2019b), the scheme avoided a loss of 3,700 ha of irrigated crops and a 3,2 USD million economic loss. Ramos et al. (2019) brought in another contribution in a similar context but proposing a variable water charge based on season hydrologic variation. Future work should focus on the integration of both negotiation and economic instruments, creating both an incentive to negotiated allocation (the alternative being paying more for the water) and signaling scarcity with a seasonally variable water charge. Hidro-economic models, as presented in Vichete & Mello Júnior (2019) can provide a methodological framework to evaluate and compare the results of a given water allocation regime, either negotiated or economic.

However, several bottlenecks to the effectivity of economic water management instruments in Brazil still persist, ranging from the need to extend it to more users, bring in other water quality parameters to the polluter payer instruments (currently only the biochemical oxygen demand is used), incomplete water users database, lack of fiscalization, less bureaucracy and a speedier use of the resources, as pointed out in Acserald et al. (2019). The discussions about the water markets corroborate this perception and indicate several of these same drawbacks prevent other economic instruments, as pointed out by Capodeferro et al. (2019). For Silva (2019), the frustration with the insufficient revenues from the water charges to finance a broader set of projects in the basin plans stems from limitations in the very political process, as the water charge values are defined in the basin committees, which often oppose to higher values.

On the other hand, we perceive a consolidation of concepts such as the integration of sanitation planning and water management, as the benefits of localized sanitation investments translate to tangible economic benefit in the context of the basin, as indicated in Dalcin & Marques (2019), Belladona et al. (2019) and Riediger & Marques (2019). The authors highlight that both sanitation and water management sectors will benefit from this integration, as sanitation investments can be optimized and water management can become more effective, less expensive and contentious. Several water utilities in Brazil face financial challenges with reduced tariffs (Fraga et al., 2019a) which makes the integration with water management even more important.

Finally, while the economic value of the water is officially recognized by Brazilian law, current practices show otherwise. Users do realize this value in their daily decisions, but the water management instruments available still fall short in properly providing economic efficiency in water allocation, investments and in signaling scarcity towards rational use. The result from this discussion indicates that there is a way, and it is up to water managers, stakeholders, researchers and politicians to bridge the gap from new concepts, perceptions and state-of-the-art methods, to practice that produces a real impact in people's lives.

Water, Energy and Food NEXUS: new perspectives and approaches in hydrology

Some of the challenges that humanity faces are recognized in the 17 Sustainable Development Goals (SDGs) of The 2030 Agenda from United Nations, as: SDG 2 – Zero Hunger, SDG 6 – Clean Water and Sanitation, SDG 7 – Affordable and Clean Energy, SDG 13 – Climate Action and SDG 16 – Life on Land. In order to guarantee food security, increasing production will require more water and energy, that are intrinsically linked to ecosystem services – such a connection is called NEXUS. With the world's population projected to reach more than 9 billion people in 2050 and global flood production is expected to increase by 70%, the understanding of the Water, Energy and Food NEXUS is a global challenge. Brazil is one of the largest food producers in the world and agribusiness (agriculture and cattle raising) represented 23% of the country's 2019 GDP (gross domestic product). Therefore, the efficient water use on this NEXUS is one of the great challenges in Brazil. In this context, there is also the uncertainty from impacts caused by future climate and land cover changes on the hydrological processes.

This session invited contributions related to Water, Energy, and Food NEXUS and ecosystem services including: (i) impacts, adaptation from climate and land cover changes over the water cycle; (ii) innovative ways to estimate hydrological fluxes over multiple scales and (iii) understanding hydrological processes from coevolution point of view to identify vulnerable/resilient basins to regional/global changes. There were 17 papers covering water, food, and energy security at multiple spatio-temporal scales (Gesualdo et al., 2019; Sone et al., 2019a). There were studies related to the development of datasets for such integration (Silva et al., 2019c), discussions on public policy related to the NEXUS (Torres et al., 2019a; Freire & Batista, 2019), insurance and socio-hydrology (Taffarello et al., 2019), the trade-off in energy production: sugar cane vs hydropower (Collischonn & Santos, 2019) and how coevolution of river basins can be used to identify vulnerable and resilient regions (Troch et al., 2015).

It was clear that understanding the Water, Food, and Energy Ecosystem services NEXUS is fundamental for Brazilian development and also for water and food supply to other countries. Discussions proposed the use of more efficient food production to face future issues related to climate change and food security (Torres et al., 2019b; Sone et al., 2019b). Pastor et al. (2019) showed that international trade needs to triplicate to support future demands, with the additional commercial flux of 10 to 20% from water abundant to water-scarce regions. In this context, one can expect more intensive land use in Brazil, a water-rich region, to support other world regions. However, to maintain sustainability it is necessary to plan the NEXUS interactions in the context of local and global perspectives (Oliveira et al., 2019c).

Water resources education in Brazil

In 2014, UNESCO started the eighth phase of the International Hydrological Program (IHP-VIII), whose main title is "Water Security" (Jimenez-Cisneros, 2015). To achieve its goal with a conclusion expected in 2021, one of the six main themes of IHP-VIII is "Education as a key to water security". Education can take place in different teaching modalities such as formal and informal. In addition, according to the level of education, it can be classified into two: i) basic, which includes early childhood education, primary and secondary education; and ii) higher education, which includes undergraduate and graduate courses. Thus, teaching can be approached in different ways and at different levels. The objective of the sessions of "Water Resources education in Brazil" (WREB) was, therefore, to provide a space for discussions and exchanges of ideas, for seeking answers to the following questions: "what", "how", "for whom", "who", "when", "where" and, finally, "why" to teach? This type of debate has been increasingly common in the academic communities, for example, the discussions on teaching presented by St. John et al. (2019).

There were two oral-presentation sessions (12 papers) and one poster-presentation session (11 papers). Informal teaching was discussed by 8 papers, meanwhile, formal education was the subject of 15 papers, among which 5, 8, and 2 treated basic education, undergraduate and graduate level, respectively. In addition to subjects directly related to pedagogical aspects (teaching methodology, content, and curriculum, etc.), the following items related to water resources were discussed: climate change, dam safety, river restoration, headwaters, Technical Course in Hydrology (CTH), students' company in university, school catchment, effluent reuse, tourism, and natural disasters. The large diversity of subjects covered in the WREB sessions is considered natural due to its main object, i.e., water resources (WR).

During the discussion time of the session, the importance of CTH in Brazil was widely and intensively confirmed by the attendants who highlighted aspects such as: i) currently, the only one CTH in Brazil is organized and coordinated by the Institute of Hydraulic Research of the Federal University of Federal University of Rio Grande do Sul – IPH/UFRGS; ii) this unique CTH is practically not working at this moment; and iii) all the teaching, research, and extension activities related to WR in its different aspects require the hydrological data which are monitored by hydro-technicians. Thus, the opinion of the participants of the sessions converged on the need for emergency actions for the maintenance of the CTH at IPH/UFRGS as well as a national expansion and creation of some CTHs in Brazil.

Discussions on pedagogical strategies, subject's content, and curriculum framework also assisted to identify situations such as: i) it is necessary to expand WR education at all the levels of education ii) the teaching quality of WR is far from a desired one, and there is an urgent necessity to revise the curriculum framework and subjects mainly in undergraduate courses; iii) teachers need to receive support from their institutions for training in the use of new teaching methodologies; iv) graduate students are concerned with the lack of pedagogical training during the course; and v) due to the lack of update, the infrastructure facilities in Brazilian institutions are far from the suitable ones evidencing the needs for buildings retrofitting and classrooms remodeling, which allow to incorporate different technologies and teaching methodologies.

Due to the issues and concerns addressed during the sessions, the whole participants felt the need of incorporating the subject "Water resources education in Brazil" on the list of central themes of ABRhidro. Furthermore, the participants decided to initiate actions in order to create the Technical Commission for Water Resources Education, in which professionals from different levels, such as professors, lecturers, students, technicians and teachers of elementary and secondary schools shall be involved. All of these people, regardless of their professions, are passively and/or actively confronted with WREB. Thus, this topic is surely important in the context of the ABRhidro's interests and will build the connection among all the subjects discussed in the future ABRhidro events.

COLLABORATIVE EXPERIENCES FROM BRAZILIAN WATER RESOURCES COMMUNITY

The network of contributing institutions (Figure 2) shows that most of the papers came from public universities, followed by a few institutions related to water resources (e.g. Brazilian Water Agency – ANA, Brazilian Geological Survey – CPRM, SABESP and ADASA Water and Waste Management Companies, Itaipu Hydroelectric Binational, Brazilian Institute for Space Research – INPE). Knowledge is being developed by institutions distributed in the different Brazilian regions. Collaborative works and exchanges of experience are present as several papers are co-authored by different institutions and most of these institutions are connected to several others. On the other hand, major clusters of collaboration are formed based on regional proximity, possibly due to convenience, legacy, and common interest in regional problems of water resources. Such a network reveals how efforts for advancing knowledge can be fragmented in Brazil, as it is also the case in the international community (Lall, 2014). Although Brazil shares water resources with other South American countries and presents water issues of great international interest, most of the papers were produced by Brazilian authors.

QUESTIONS ADDRESSED BY THE BRAZILIAN WATER COMMUNITY

In order to understand how those sessions are related, we analyzed the co-occurrence of words in the titles and descriptions of each special session using the VOS Viewer software. In the analysis, words with a minimum number of occurrences equal to 2 were considered to eliminate words of low significance. The analysis method considers the relationship between words according to the number of times they occur together in the titles and descriptions of the different special sessions. We found 3 clusters of sessions using the words addressed in the themes of the special sessions (Figure 3). We also asked the conveners to read the special sessions descriptions. As a postscript, they expressed that most sessions are closely related to at least 5 other ones which is similar to what was independently found in with the word grouping (Figure 3). The Green cluster relates to large scale hydrology, including water issues as energy and food, systems of reservoirs, climate change impacts, and estimation technology based on remote sensing. The red cluster relates to hydrological processes including ecohydrology, sediments, floods, and environmental fluid mechanics. The blue cluster relates to interfaces with society, including disasters, climate impacts, education, and water resources management.

The contributions were categorized according to the type of scientific question ("How", "What", "Why") of the UPH

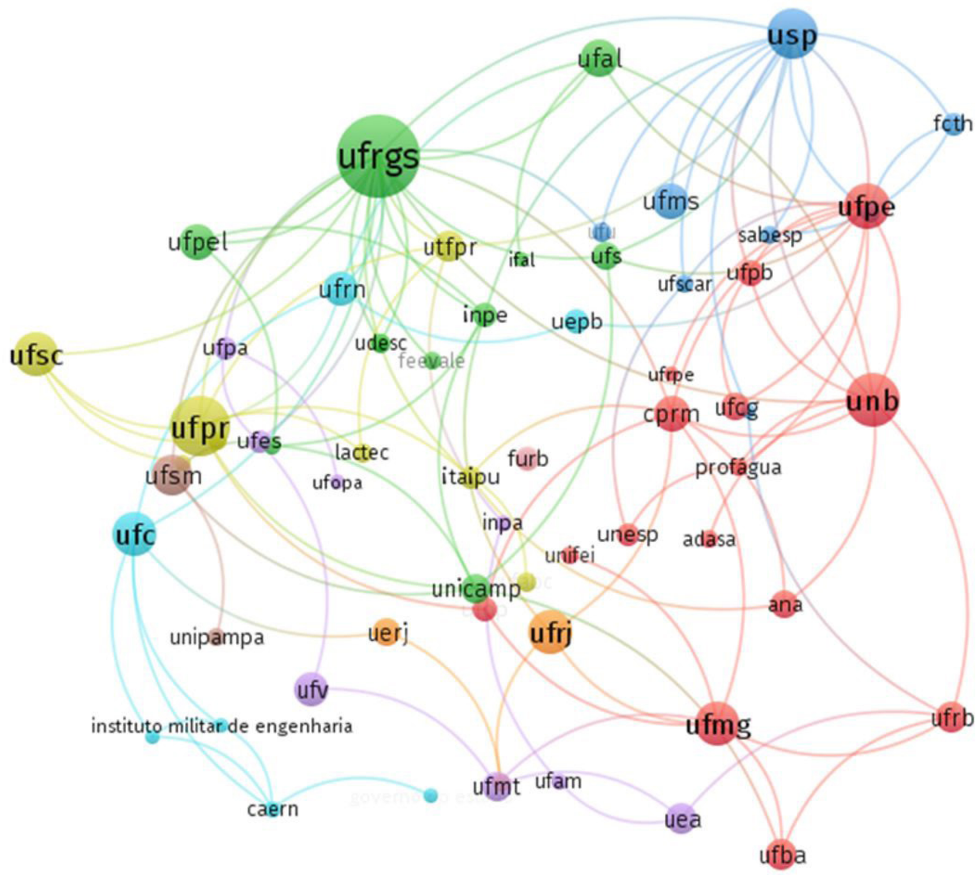

Figure 2. Network of institutions with at least 5 papers at XXIII SBRH 2019. The network was extracted using the list of coauthors of each paper. The size of the circles is proportional to the total number of papers. Colors represent large clusters of collaboration networks.

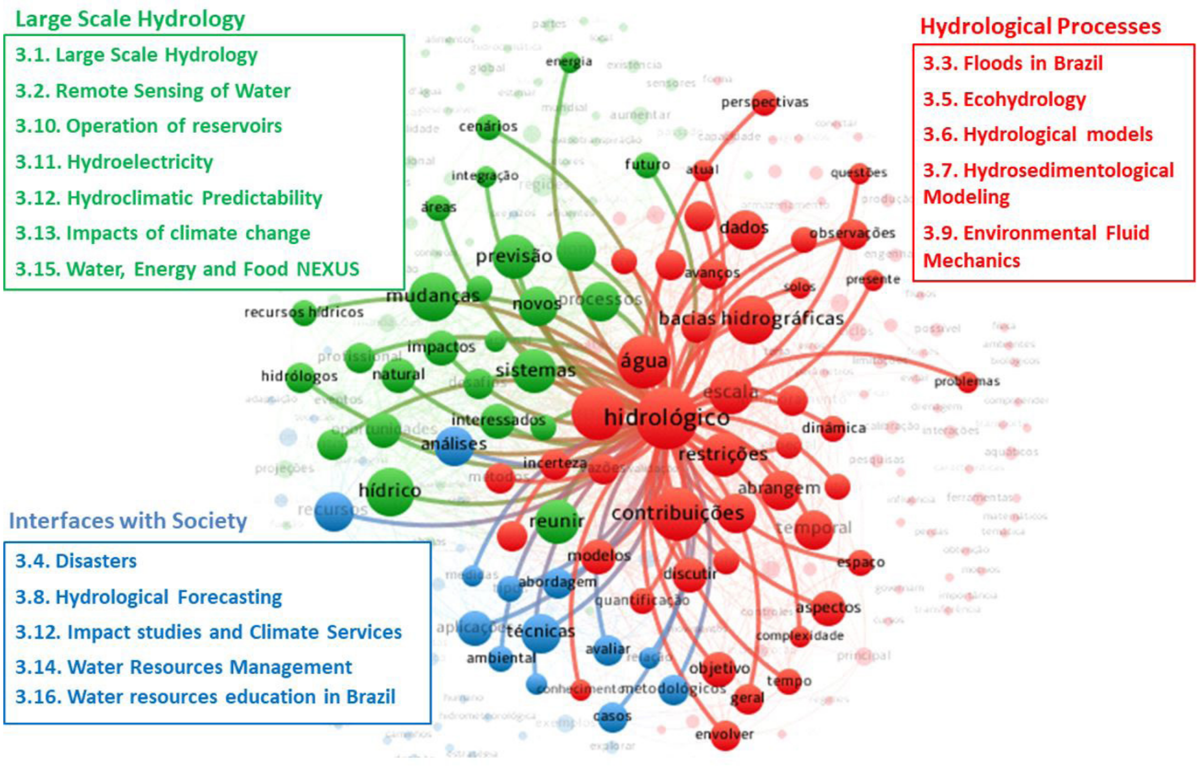

Figure 3. Network words extracted from the description of the special sessions. The colored clusters are related to the similarity of word count and connection among each of the special sessions.

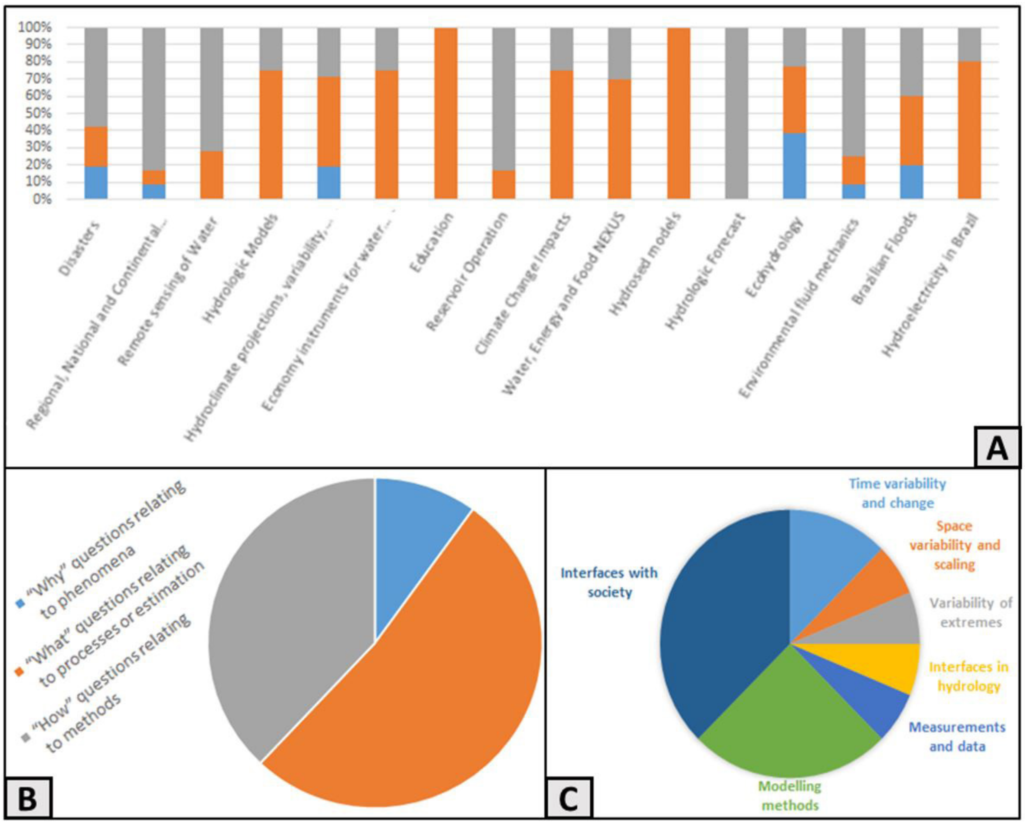

Figure 4. Distribution of the contributions of each special session of XXIII SBRH 2019 categorized according to the type of scientific question (A, B) and groups of Unsolved Problems in Hydrology (C) from Blöschl et al. (2019a).

(Blöschl et al., 2019a). Conveners also reported on how the contributions from their sessions related to the others.

Unsolved problems in hydrology can be classified into three types of questions: (i) "Why" questions, relating to the explanation of why some phenomena happen or exist; (ii) "What" questions, relating to the estimation, identification and recognition of some phenomena; and (iii) "How" questions, relating to methods (Blöschl et al., 2019a). In general, most papers presented at the special sessions of XXIII SBRH 2019 were related to "What" and "How" questions (Figure 4), i.e., papers were more related to water resources practice than to the detection and comprehension of phenomena. For example, contributions on themes as hydrological forecast, reservoir operation, remote sensing and continental hydrology were more focused on methods ("How"). Sessions related to Education, Climate Change impacts, Hydroelectricity, NEXUS, Water Management presented contributions related to characterization, quantification, or prediction of phenomena ("What"). Deeper investigations for phenomena comprehension ("Why") were rare and observed for themes as related to Disasters, Climate, Ecohydrology, and Floods.

This predominance can also be acknowledged if we arrange the special session according to the seven general themes of the 23 unsolved problems in hydrology, based on conveners reports and interpretation: (i) Interfaces with society, (ii) Modelling methods, (iii) Interfaces in hydrology, (iv) Time Variability and Change, (v) Variability of Extremes, (vi) Space variability and scaling, and (vii) Measurement and data. There were more contributions related to the themes (i) and (ii). Hence, a clear necessity and opportunity can be seen for more research on phenomena comprehension and subjects like the themes (iii) to (vii).

CONCLUSIONS AND EMERGENT CHALLENGES FOR THE BRAZILIAN WATER COMMUNITY

This paper presents the state of the art of knowledge building by the Brazilian water community. Based on the contributions to the XXIII Brazilian Water Resources Symposium (XXIII SBRH 2019) and on the conveners' report, we conclude and propose a few challenges for the Brazilian water community.

i. An overview of the advances and debates of the XXIII SBRH 2019 is presented in Sections 2 and 3 based on reports from the conveners of the special sessions covering a wide range of topics as Climate Change, Disasters, Hydrologic and Hydraulic Modeling, Large Scale Hydrology, Education, Water Resources Management and Remote Sensing of Water. It includes scientific motivations, the synthesis of the contributions and the debates during the event as well as the perspectives and future challenges for specific themes. This exercise highlights the unique diversity of natural and human water features in Brazil that offers a great opportunity for understanding coupled hydrological and societal systems.

Challenge 1: To recognize the reported lessons learnt and plan future research taking advantage of the identified questions and opportunities.

Challenge 2: To enhance the culture of synthesis analysis to build a common scientific agenda on unsolved problems in hydrology.

ii. There is a great potential for a collaborative environment. The ABRhidro community successfully cooperated in the first open experience on the organization of technical sessions, allowing more focus and interactions around a specific interest. Paper contributions show an intense network of collaboration in Brazil. Most of the papers came from Brazilian academic institutions, and with some degree of regional fragmentation, possibly due to geographical convenience, legacy, or common interest on regional scale water resources issues.

Challenge 3: To develop a cohesive collaboration network on activities and around a common scientific agenda.

Challenge 4: To enhance the participation of other technical and professional communities outside of academia aiming at societal relevant knowledge building.

Challenge 5: To enhance collaboration with international communities, with two-way sharing of knowledge and efforts on water sciences developments, especially with other Latin American countries with shared water issues.

iii. Several studies orbited around Large Scale Hydrology, Hydrological Processes, and Water Interfaces with Society. There is an opportunity for more interdisciplinary research with sister sciences (e.g. environmental and earth system sciences, meteorology, ecology, geology, social sciences and technologies for clean water). Most of the contributions focused on water resources practice, with more investigations on Methods ("How" questions) and estimation, quantification, and prediction of water-related phenomena ("What" questions). There is a clear opportunity for more research on themes focused on phenomena comprehension ("Why" questions).

Challenge 6: To enhance diversity of research approaches and themes, ranging from practical methods, technologies, and quantification of water resources to deepen water phenomena comprehension in preparation for future and unprecedented water issues.

Even though we recognize that there are remaining biases related to the topics covered on the XXIII SBRH special sessions, we hope that this synthesis will motivate more research on the topics that were only partially addressed during the symposium. As it is expected in the water sciences, we identified that most of the papers were related to methodologies and practical problems faced by society. However, it is clear that our better planning and management of the water resources are strongly dependent on our knowledge of hydrology and sister sciences. Just as Lall (2014) suggested that we think of the concept of "one water, one world", the theme "water connects" of the XXIII SBRH made us think of Lall's concept. Based on an understanding of the practical and scientific problems at different scales, we can decide the best path to guarantee adequate water security to the nation. Furthermore, we believe it is high time for the ABRhidro to become more active internationally and to use its regional knowledge to contribute to the tackling of global water issues.

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REFERENCES

Abatti, B. H., Paul, L. R., Tschöke, G. V., & Michel, G. P. (2019). Mapeamento de áreas suscetíveis a inundação no município de Rio do Sul (SC) por meio do modelo HANS. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Acserald, M. V., Souza, M. C., Bastos, F. M., & Formiga-Johnsson, R. M. (2019). Aperfeiçoando a cobrança pelo uso da água no estado do Rio de Janeiro: a evolução do preço público unitário. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Agência Nacional de Águas – ANA. (2019a). *Conjuntura dos recursos hídricos no Brasil 2019: relatório pleno*. Brasília. Retrieved in 2020, May 6, from http://conjuntura.ana.gov.br/static/media/conjuntura-completo.bb39ac07.pdf

Agência Nacional de Águas – ANA. (2019b). *Plano Nacional de Segurança Hídrica*. Brasília. Retrieved in 2020, May 6, from http://arquivos.ana.gov.br/pnsh/pnsh.pdf

Agência Nacional de Energia Elétrica – ANEEL. (2020). *Sistema de Informações de Geração da ANEEL*. Retrieved in 2020, May 6, from http://www.aneel.gov.br/siga

Almagro, A., Oliveira, P. T. S., Nearing, M. A., & Hagemann, S. (2017). Projected climate change impacts in rainfall erosivity over Brazil. *Scientific Reports*, *7*(1), 8130. PMid:28811512. http://dx.doi.org/10.1038/s41598-017-08298-y.

Alves, J. M. A. C., Lins, R. C., Fragoso Junior, C. R., & Marques, D. M. L. M. (2019a). Utilização de modelos semi-empíricos para estimação da concentração de clorofila-a em um sistema estuarino lagunar tropical. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Alves, M. E. P., Fan, F. M., & Fleischmann, A. S. (2019b). Simulação de rompimento de barragens em cascata com o modelo MGB. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Amorim, L. F., Martins, J. R. S., Vinçon-Leite, B., & Soulignac, F. (2019). Forecasting water column stratification and mixing episodes based onatmospheric driving forces. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Anache, J. A. A., Wendland, E. C., Rosalem, L. M. P., Youlton, C., & Oliveira, P. T. S. (2019). Hydrological trade-offs due to different land covers and land uses in the Brazilian Cerrado. *Hydrology and Earth System Sciences*, *23*(3), 1263. http://dx.doi.org/10.5194/hess-23-1263-2019.

Andrade, A. C. F., Paiva, R. C. D., Barbosa, C. C. F., Novo, E. M. L. M., & Rudorff, C. M. (2019). Abordagem probabilística para estimativa da batimetria de lagos e reservatórios utilizando imagens orbitais. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Andrade, J. M. D., Cunha, J. E. B. L., Silva, J. N. C., Bezerra, U. A., & Rufino, I. A. A. (2019a). Classificação da cobertura do solo da caatinga através dos subprodutos do SEBAL. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Andrade, V. S., Rosman, P. C. C., & Azevedo, J. P. S. (2019b). Parte I: uso de modelagem computacional para análises de hidrodinâmica ambiental na baía de Guanabara. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Araujo, A. N. D., Freitas, C., Paulek, D. M., Buba, H., Oliveira, P. D., Nascimento, J. J., Almeida, R., Pereira, R. S. M., & Rescigno, J. V. (2019). Operação hidráulica dos reservatórios da cascata do Rio Iguaçu. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Associação Brasileira de Recursos Hídricos – ABRH. (2019a). *XXIII Simpósio Brasileiro de Recursos Hídrico*. Retrieved in 2020, August 29, from https://eventos.abrh.org.br/xxiiisbrh/

Associação Brasileira de Recursos Hídricos – ABRH. (2019b, November 28). *A água conecta*. Retrieved in 2020, August 29, from https://site.abrhidro.org.br/cartas/foz-do-iguacu-2019/

Avila, I. G., Nascimento, G. D. S., Ruhoff, A. L., Chalegre, C. L. B., Marques, D. M. L. M., Tavares, M. H., Menegon, I., & Fragoso Junior, C. R. (2019). Estudo preliminar da dinâmica da temperatura de lagoas rasas costeiras subtropicais em cadeia. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Bárbara Neto, M., Boeira, L. D. S., Terra, V. S. S., & Fiorio, P. R. (2019). Análise da assinatura espectral da água em ambiente estuarino da Lagoa dos Patos - RS. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Barbosa, A. V. F., & Becker, V. (2019). Influência de eventos hidrológicos extremos na qualidade da água de reservatórios na região tropical semiárida. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Bartiko, D., Oliveira, D. Y., Bonumá, N. B., & Chaffe, P. L. B. (2019). Consideração de incerteza e não estacionariedade na análise de frequência de cheias no Brasil. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Belladona, R., Marques, G. F., & Vargas, T. (2019). Análise de custos de oportunidade na gestão de recursos hídricos: uma revisão. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Best, J. (2019). Anthropogenic stresses on the world's big rivers. *Nature Geoscience*, *12*(1), 7-21. http://dx.doi.org/10.1038/s41561-018-0262-x.

Bierkens, M. F. P. (2015). Global hydrology 2015: state, trends, and directions. *Water Resources Research*, *51*(7), 600-612. http://dx.doi.org/10.1002/2015WR017173.

Billerbeck, C., & Mello Júnior, A. V. (2019). Cenários alternativos de precipitação para estudos de mudanças climáticas na bacia do rio Piracicaba. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Blöschl, G., Bierkens, M. F. P., Chambel, A., Cudennec, C., Destouni, G., Fiori, A., Kirchner, J. W., McDonnell, J. J., Savenije, H. H. G., Sivapalan, M., Stumpp, C., Toth, E., Volpi, E., Carr, G., Lupton, C., Salinas, J., Széles, B., Viglione, A., Aksoy, H., Allen, S. T., Amin, A., Andréassian, V., Arheimer, B., Aryal, S. K., Baker, V., Bardsley, E., Barendrecht, M. H., Bartosova, A., Batelaan, O., Berghuijs, W. R., Beven, K., Blume, T., Bogaard, T., Borges de Amorim, P., Böttcher, M. E., Boulet, G., Breinl, K., Brilly, M., Brocca, L., Buytaert, W., Castellarin, A., Castelletti, A., Chen, X., Chen, Y., Chen, Y., Chifflard, P., Claps, P., Clark, M. P., Collins, A. L., Croke, B., Dathe, A., David, P. C., de Barros, F. P. J., de Rooij, G., Di Baldassarre, G., Driscoll, J. M., Duethmann, D., Dwivedi, R., Eris, E., Farmer, W. H., Feiccabrino, J., Ferguson, G., Ferrari, E., Ferraris, S., Fersch, B., Finger, D., Foglia, L., Fowler, K., Gartsman, B., Gascoin, S., Gaume, E., Gelfan, A., Geris, J., Gharari, S., Gleeson, T., Glendell, M., Gonzalez Bevacqua, A., González-Dugo, M. P., Grimaldi, S., Gupta, A. B., Guse, B., Han, D., Hannah, D., Harpold, A., Haun, S., Heal, K., Helfricht, K., Herrnegger, M., Hipsey, M., Hlaváčiková, H., Hohmann, C., Holko, L., Hopkinson, C., Hrachowitz, M., Illangasekare, T. H., Inam, A., Innocente, C., Istanbulluoglu, E., Jarihani, B., Kalantari, Z., Kalvans, A., Khanal, S., Khatami, S., Kiesel, J., Kirkby, M., Knoben, W., Kochanek, K., Kohnová, S., Kolechkina, A., Krause, S., Kreamer, D., Kreibich, H., Kunstmann, H., Lange, H., Liberato, M. L. R., Lindquist, E., Link, T., Liu, J., Loucks, D. P., Luce, C., Mahé, G., Makarieva, O., Malard, J., Mashtayeva, S., Maskey, S., Mas-Pla, J., Mavrova-Guirguinova, M., Mazzoleni, M., Mernild, S., Misstear, B. D., Montanari, A., Müller-Thomy, H., Nabizadeh, A., Nardi, F., Neale, C., Nesterova, N., Nurtaev, B., Odongo, V. O., Panda, S., Pande, S., Pang, Z., Papacharalampous, G., Perrin, C., Pfister, L., Pimentel, R., Polo, M. J., Post, D., Prieto Sierra, C., Ramos, M.-H., Renner, M., Reynolds, J. E., Ridolfi, E., Rigon, R., Riva, M., Robertson, D. E., Rosso, R., Roy, T., Sá, J. H. M., Salvadori, G., Sandells, M., Schaefli, B., Schumann, A., Scolobig, A., Seibert, J., Servat, E., Shafiei, M., Sharma, A., Sidibe, M., Sidle, R. C., Skaugen, T., Smith, H., Spiessl, S. M., Stein, L., Steinsland, I., Strasser, U., Su, B., Szolgay, J., Tarboton, D., Tauro, F., Thirel, G., Tian, F., Tong, R., Tussupova, K., Tyralis, H., Uijlenhoet, R., van Beek, R., van der Ent, R. J., van der Ploeg, M., Van Loon, A. F., van Meerveld, I., van Nooijen, R., van Oel, P. R., Vidal, J.-P., von Freyberg, J., Vorogushyn, S., Wachniew, P., Wade, A. J., Ward, P., Westerberg,

I. K., White, C., Wood, E. F., Woods, R., Xu, Z., Yilmaz, K. K., & Zhang, Y. (2019a). Twenty-three unsolved problems in hydrology (UPH): a community perspective. *Hydrological Sciences Journal*, *64*(10), 1141-1158. http://dx.doi.org/10.1080/02626667.2019.1620507.

Blöschl, G., Hall, J., Parajka, J., Perdigão, R. A. P., Merz, B., Arheimer, B., Aronica, G. T., Bilibashi, A., Bonacci, O., Borga, M., Čanjevac, I., Castellarin, A., Chirico, G. B., Claps, P., Fiala, K., Frolova, N., Gorbachova, L., Gül, A., Hannaford, J., Harrigan, S., Kireeva, M., Kiss, A., Kjeldsen, T. R., Kohnová, S., Koskela, J. J., Ledvinka, O., Macdonald, N., Mavrova-Guirguinova, M., Mediero, L., Merz, R., Molnar, P., Montanari, A., Murphy, C., Osuch, M., Ovcharuk, V., Radevski, I., Rogger, M., Salinas, J. L., Sauquet, E., Šraj, M., Szolgay, J., Viglione, A., Volpi, E., Wilson, D., Zaimi, K., & Živković, N. (2017). Changing climate shifts timing of European Floods. *Science*, *357*(6351), 588-590. PMid:28798129. http://dx.doi.org/10.1126/science.aan2506.

Blöschl, G., Hall, J., Viglione, A., Perdigão, R. A. P., Parajka, J., Merz, B., Lun, D., Arheimer, B., Aronica, G. T., Bilibashi, A., Boháč, M., Bonacci, O., Borga, M., Čanjevac, I., Castellarin, A., Chirico, G. B., Claps, P., Frolova, N., Ganora, D., Gorbachova, L., Gül, A., Hannaford, J., Harrigan, S., Kireeva, M., Kiss, A., Kjeldsen, T. R., Kohnová, S., Koskela, J. J., Ledvinka, O., Macdonald, N., Mavrova-Guirguinova, M., Mediero, L., Merz, R., Molnar, P., Montanari, A., Murphy, C., Osuch, M., Ovcharuk, V., Radevski, I., Salinas, J. L., Sauquet, E., Šraj, M., Szolgay, J., Volpi, E., Wilson, D., Zaimi, K., & Živković, N. (2019b). Changing climate both increases and decreases European river floods. *Nature*, *573*(7772), 108-111. PMid:31462777. http://dx.doi.org/10.1038/s41586-019-1495-6.

Borges, P. A., & Chaffe, P. B. (2019). Towards a comprehensive characterization of evidence in synthesis assessments: the climate change impacts on the Brazilian water resources. *Climatic Change*, *155*(1), 37-57. http://dx.doi.org/10.1007/s10584-019-02430-9.

Borges, P. A., Madruga, J., Brito, A., Freitas, E., Câmara, A. C., Chou, S. C., & Scholze, M. (2019a). Inventário nacional de serviços climáticos no âmbito dos recursos hídricos. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Borges, P. A., Souza, K. I. S. D., & Chaffe, P. L. B. (2019b). Ferramenta para visualização de síntese de estudos dos impactos das mudanças climáticas nos recursos hídricos do Brasil. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Brasil. (1997, January 8). Lei nº 9.433, de 8 de janeiro de 1997. Institui a Política Nacional de Recursos Hídricos, cria o Sistema Nacional de Gerenciamento de Recursos Hídricos, regulamenta o inciso XIX do art. 21 da Constituição Federal, e altera o art. 1º da Lei nº 8.001, de 13 de março de 1990, que modificou a Lei nº 7.990, de 28 de dezembro de 1989. *Diário Oficial [da] República Federativa do Brasil*, Brasília.

Brasil. Agência Nacional de Águas – ANA. Agência Nacional de Energia Elétrica – ANEEL. (2010, August 10). Resolução Conjunta ANA/ANEEL nº 03 de 10/08/2010. Estabelecer as condições e os procedimentos a serem observados pelos concessionários e autorizados de geração de energia hidrelétrica para a instalação, operação e manutenção de estações hidrométricas visando ao monitoramento pluviométrico, limnimétrico, fluviométrico, sedimentométrico e de qualidade da água associado a aproveitamentos hidrelétricos, e dar outras providências. *Diário Oficial [da] República Federativa do Brasil*, Brasília.

Brêda, J. P. L. F., Paiva, R. C. D., Collischonn, W., Siqueira, V. A., & Fleischmann, A. S. (2019a). Aprimoramento das seções de modelos hidrodinâmicos de grande escala com a utilização de dados de novas bases globais. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Brêda, J. P. L. F., Paiva, R. C. D., Siqueira, V. A., Collischonn, W., & Bravo, J. M. (2019b). Efeito das mudanças climáticas nos recursos hídricos da América do Sul. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Buchir, L. M. S. T., Detzel, D. H. M., Mine, M. R. M., Bessa, M. R., Fernandes, C. V. S., & Kishi, R. T. (2019). Vulnerability and adaptation capacity of river basins to climate change: a different approach to climate vulnerability index. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Bueno, M. L., Bertone, A. C., Keppen, R. P. T., Detzel, D. H. M., & Souza, W. L. (2019). Usinas hidrelétricas com reservatório de acumulação e a fio d'água: estudo de caso aplicado à Bacia do Rio Iguaçu. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Bueno, R. D. C., & Bleninger, T. (2019). Dinâmica de lagos em períodos de estratificação térmica: ocorrência de seichas internas. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Buffon, F. T., Rolim, F. E., & Marcuzzo, F. F. N. (2019). Características das seções transversais na modelagem da propagação do escoamento na Bacia do Rio Uruguai. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Bussi, G., Dadson, S. J., Prudhomme, C., & Whitehead, P. G. (2016). Modelling the future impacts of climate and land-use change on suspended sediment transport in the River Thames (UK). *Journal of Hydrology*, *542*, 357-372. http://dx.doi.org/10.1016/j.jhydrol.2016.09.010.

Caballero, C. B., Guedes, H. A. S., Fraga, R. S., Mendes, K. G. P., Andrade, A. C. F., & Martins, V. S. (2019). Sensoriamento remoto aplicado ao estudo de águas interiores: monitoramento de clorofila-a em uma lagoa subtropical. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Capodeferro, M. W., Kelman, J., & Azevedo, J. P. S. (2019). A introdução de mercados de água como instrumento de alocação de recursos hídricos: o contexto brasileiro. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Cardozo, G., & Michel, G. P. (2019). Utilização da ferramenta r.randomwalk para a avaliação de movimentos de massa na bacia do rio Mascarada - RS. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Casagrande, L., Tomasella, J., Alvalá, R. C. S., Bottino, M. J., & Caram, R. O. (2017). Early flood warning in the Itajaí-Açu River basin using numerical weather forecasting and hydrological modeling. *Natural Hazards*, *88*(2), 741-757. http://dx.doi.org/10.1007/s11069-017-2889-0.

Cassalho, F., Beskow, S., Mello, C. R., Moura, M. M., Oliveira, L. F., & Aguiar, M. S. (2019). Artificial intelligence for identifying hydrologically homogeneous regions: a state-of-the-art regional flood frequency analysis. *Hydrological Processes*, *33*(7), 1101-1116. http://dx.doi.org/10.1002/hyp.13388.

Centre for Research on the Epidemiology of Disasters – CRED. (2019). *Emergency Events Database (EM-DAT)*. Brussels: OFDA/CRED. Retrieved in 2019, October 17, from http://www.em-dat.net/

Chagas, J. P., Sousa, M. M. D., Oliveira, A. K. B., & Gomes Miguez, M. (2019). Estudo de propagação de onda de cheia pela ruptura da barragem UHE Paranapanema. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Chagas, V. B. P., & Chaffe, P. L. B. (2019a). Análise das tendências de chuva no Brasil, de 1980 a 2015. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Chagas, V. B. P., & Chaffe, P. L. B. (2019b). Não-estacionariedade é inevitável! Causas das recentes mudanças de vazão no Brasil. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Chan, P. D. S., Costa, F. D. S., Damazio, J. M., Kyrillos, D., Raupp, I. P., & Rotunno Filho, O. C. (2019). Análise de estacionariedade de vazões máximas para o planejamento de controle de cheias em aproveitamentos hidroelétricos. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Collischonn, B., & Santos, P. F. B. (2019). Análise de preferência hidroenergética: cana-de-açúcar x hidrelétricas. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Collischonn, W., & Kobiyama, M. (2019a). A hidrologia da cabeça d'água (1): ocorrências e observações no Brasil. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Collischonn, W., & Kobiyama, M. (2019b). A hidrologia da cabeça d'água (2): formação de frente de onda abrupta. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Collischonn, W., & Kobiyama, M. (2019c). A hidrologia da cabeça d'água (3): síntese. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Colman, C. B., Garcia, C. M. P., Pereira, R. B., Shinma, E. A., Lima, F. E., Gomes, A. O., & Oliveira, P. T. S. (2018). Different approaches to estimate the sediment yield in a tropical watershed. *Revista Brasileira de Recursos Hídricos*, *23*, e47. http://dx.doi.org/10.1590/2318-0331.231820170178.

Colombo, G. T., & Mannich, M. (2019). Estimativa da temperatura da água em rios utilizando a média móvel da temperatura do ar. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Correa, A. C. S. S., & Silva, M. J. G. D. (2019). Avaliação do fluxo de água entre Abunã e Porto Velho, durante a cheia de 2014. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Cunningham, C., Zang, R., Cuartas, A., & Leal, K. (2019). Subseasonal prediction of extreme streamflow over the Upper São Francisco basin. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Dalcin, A. P., & Marques, G. F. (2019). Proposta de integração de instrumentos de gestão dos recursos hídricos. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

David, P. C., Chagas, V. B. P., & Chaffe, P. L. B. (2019a). Uso de assinaturas hidrológicas para classificação de bacias hidrográficas do Brasil. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

David, P. C., Oliveira, D. Y., Chagas, V. B. P., & Chaffe, P. L. B. (2019b). Investigação da relação entre estruturas de modelos conceituais e características hidrológicas. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Detzel, D. H. M., Martini Filho, L. R., Rangel, L. M. A., Bessa, M. R., & Geus, K. (2019). Acerca do período crítico das usinas hidrelétricas brasileiras. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Domingues, L. M., & Rocha, H. R. (2019). Impacto do aquecimento e secamento do ar nos fluxos hidrológicos: um estudo na bacia do rio Jaguari. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Empresa de Pesquisa Energética – EPE. Ministério de Minas e Energia – MME. (2019). *Plano decenal de expansão de energia 2029*. Brasília: MME/EPE.

Fagundes, H. O., & Bravo, J. M. (2019). Calibração automática de um modelo de sedimentos em regiões com escassez de dados. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Fan, F. M., Collischonn, W., Buarque, D. C., Tucci, C. E. M., & Botelho, L. C. M. (2013). Desenvolvimento e avaliação de um sistema de previsão hidrológica distribuída para a região da UHE Três Marias. In *Anais do XX Simpósio Brasileiro de Recursos Hídricos*. Porto Alegre: ABRH.

Fan, F. M., Collischonn, W., Quiroz, K., Sorribas, M. V., Buarque, D. C., & Siqueira, V. A. (2016). Flood forecasting on the Tocantins River using ensemble rainfall forecasts and real-time satellite rainfall estimates. *Journal of Flood Risk Management*, *9*(3), 278-288. http://dx.doi.org/10.1111/jfr3.12177.

Fernandes, L. G., Grimm, A. M., & Detzel, D. H. M. (2019). Impactos da oscilação de Madden-Julian em anos de La Niña na precipitação da América do Sul. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Fernandes, N. F., Guimarães, R. F., Gomes, R. A. T., Vieira, B. C., Montgomery, D. R., & Greenberg, H. (2001). Condicionantes geomorfológicos dos deslizamentos nas encostas: avaliação de metodologias e aplicação de modelo de previsão de áreas susceptíveis. *Revista Brasileira de Geomorfologia*, *2*(1), 51-71. http://dx.doi.org/10.20502/rbg.v2i1.8.

Ferreira, P. M. D. L., Baptista, V. S. G., & Paz, A. R. (2019). Análise comparativa de produtos de sensoriamento remoto e o modelo MBG-IPH no Nordeste brasileiro. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Fleischmann, A. S., Brêda, J. P. L. F., Fan, F. M., & Wongchuig, S. (2019b). Um modelo hidrológico-hidrodinâmico da bacia do paraná e seus reservatórios. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Fleischmann, A., Paiva, R., & Collischonn, W. (2019a). Can regional to continental river hydrodynamic models be locally relevant? A cross-scale comparison. *Journal of Hydrology X*, *3*, 100027. http://dx.doi.org/10.1016/j.hydroa.2019.100027.

Föeger, L. B., Buarque, D. C., Pontes, P. R. M., & Fagundes, H. (2019a). Modelagem hidrossedimentológica com propagação inercial de vazões. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Föeger, L. B., Buarque, D. C., Pontes, P. R. M., & Fagundes, H. (2019b). Simulação hidrológica com propagação inercial de vazão: estudo de caso na bacia do rio Madeira. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Fontana, R. B., & Collischonn, W. (2019). Remote sensing and GIS based analysis of groundwater dependent ecosystems in the Brazilian Cerrado. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Fraga, C. I. M., Alves, C. M. A., & Nogueira, J. M. (2019a). Tarifa de abastecimento de água: indícios do desempenho das companhias de saneamento em capitais brasileiras. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Fraga, R. S., Guedes, H. A. S., Caballero, C. B., Mendes, K. G. P., Martins, V. S., Andrade, A. C. F., & Fonseca, M. O. (2019b). Modelagem empírica de sólidos em suspensão na Lagoa Mirim, RS, utilizando dados do MSI/SENTINEL-2. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Freire, R. C., & Batista, J. A. N. (2019). Relações bilaterais entre água e alimento na bacia hidrográfica do rio Atibaia. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Freitas, C., Araujo, A. N. D., Buba, H., Muller, I. I., & Gibertoni, R. F. C. (2019). Avaliação dos procedimentos de operação hidráulica da UHE Mauá. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Galy, V., Peucker-Ehrenbrink, B., & Eglinton, T. (2015). Global carbon export from the terrestrial biosphere controlled by erosion. *Nature*, *521*(7551), 204-207. PMid:25971513. http://dx.doi.org/10.1038/nature14400.

Gama, C. H. A., Paiva, R. C. D., & Collischonn, W. (2019). SOPREVA - Sistema operacional de previsão de vazões, baseado em modelo hidrológico concentrado e assimilação de dados. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Gesualdo, G. C., Oliveira, P. T., Rodrigues, D. B. B., & Gupta, H. V. (2019). Assessing water security in the São Paulo metropolitan region under projected climate change. *Hydrology and Earth System Sciences*, *23*(12), 4955-4968. http://dx.doi.org/10.5194/hess-23-4955-2019.

Giacomazzo, A. P., Alves, C. M. A., & Matsushita, R. Y. (2019). Modelagem de vazões afluentes ao reservatório do Descoberto (Distrito Federal) por processos de memória longa sazonal. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Giacomelli, L., Nectoux, M., Fan, F. M., Fleischmann, A. S., Siqueira, V. A., Collischonn, W., & Custódio, M. (2019). Previsão de cheias e produção de avisos no estado do Rio Grande do Sul através da sala de situação SEMA/RS e modelo MGB. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Gomes, M. D. G., Medeiros, J. D. F. D., & Maia, A. G. (2019a). Otimização da alocação de água em reservatório semiárido em cenários de escassez hídrica. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Gomes, Y. R. M., Marques, L. A., & Souza, C. F. (2019b). Não estacionariedade de regimes hidrológicos: análise da sua consideração e revisão de técnicas de estimativa. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH

Granadier, V., & Rauen, W. B. (2019). Importância relativa da evolução de pequenas dunas na modelagem hidrossedimentológica fluvial. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Guirro, M. O., & Michel, G. P. (2019). Análise de formação e rompimento de barragens naturais no evento extremo de 2017 na região de Rolante (RS). In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Hrachowitz, M., & Clark, M. P. (2017). HESS opinions: the complementary merits of competing modelling philosophies in hydrology. *Hydrology and Earth System Sciences*, *21*(8), 3953-3973. http://dx.doi.org/10.5194/hess-21-3953-2017.

Hrachowitz, M., Savenije, H. H. G., Blöschl, G., McDonnell, J. J., Sivapalan, M., Pomeroy, J. W., Arheimer, B., Blume, T., Clark, M. P., Ehret, U., Fenicia, F., Freer, J. E., Gelfan, A., Gupta, H. V., Hughes, D. A., Hut, R. W., Montanari, A., Pande, S., Tetzlaff, D., Troch, P. A., Uhlenbrook, S., Wagener, T., Winsemius, H. C., Woods, R. A., Zehe, E., & Cudennec, C. (2013). A decade of Predictions in Ungauged Basins (PUB): a review. *Hydrological Sciences Journal*, *58*(6), 1198-1255. http://dx.doi.org/10.1080/02626667.2013.803183.

Intergovernmental Panel on Climate Change – IPCC. (2014). *Climate change 2014: impacts, adaptation, and vulnerability: Working Group II contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change*. New York: Cambridge University Press.

Jimenez-Cisneros, B. (2015). Responding to the challenges of water security: the Eighth Phase of the International Hydrological Programme, 2014-2021. *IAHS Publication*, *366*, 10-19. http://dx.doi.org/10.5194/piahs-366-10-2015.

Juliani, B. H. T., Ferreira, I. A., Okawa, C. M. P., & Zuffo, A. C. (2019). Estudo de estacionariedade na série histórica de precipitação da estação Tibagi, Paraná. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Kayser, R., Ruhoff, A. L., & Kich, E. D. M. (2019). Avaliação de séries temporais de evapotranspiração em bacia com intensa atividade agrícola no Sul do Brasil. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Khenayfis, L. S., Braga, R. S., & Kligerman, A. S. (2019). Metodologia para determinação de curvas vazão defluente-nível de jusante em aproveitamentos hidrelétricos. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Kirchner, J. W. (2006). Getting the right answers for the right reasons: linking measurements, analyses, and models to advance the science of hydrology. *Water Resources Research*, *42*(3), W03S04. http://dx.doi.org/10.1029/2005WR004362.

Kobiyama, M., Caron, B. P., & Paixão, M. A. (2019). Hazard connectivity index and its application for debris-flow disaster management. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Lall, U. (2014). Debates: the future of hydrological sciences: a (common) path forward? *Water Resources Research*, *50*, 5335-5341. http://dx.doi.org/10.1002/2014WR015402.

Lettenmaier, D. P., Alsdorf, D., Dozier, J., Huffman, G. J., Pan, M., & Wood, E. F. (2015). Inroads of remote sensing into hydrologic science during the WRR era. *Water Resources Research*, *51*(9), 7309-7342. http://dx.doi.org/10.1002/2015WR017616.

Lima, C. H. R., & Arteaga, Y. V. L. (2019). Impacto das mudanças climáticas em índices de Monção da América do Sul. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Lins, R. C., Marques, D. M. L. D. M., & Fragoso Junior, C. R. (2019). Calibração de modelos empíricos de análise derivativa de curvas hiperespectrais para estimativa de constituintes opticamente ativos em um sistema estuarino-lagunar. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

López-Vicente, M., & Bem-Salem, N. (2019). Computing structural and functional flow and sediment connectivity with a new aggregated index: a case study in a large Mediterranean catchment. *The Science of the Total Environment*, *651*(Pt 1), 179-191. PMid:30227288. http://dx.doi.org/10.1016/j.scitotenv.2018.09.170.

Mamede, G. L., Guentner, A., Medeiros, P. H. A., Araújo, J. C., & Bronstert, A. (2018). Modeling the effect of multiple reservoirs on water and sediment dynamics in a semiarid catchment in Brazil. *Journal of Hydrologic Engineering*, *23*(12), 05018020. http://dx.doi.org/10.1061/(ASCE)HE.1943-5584.0001701.

Martins, L. K. L. A., Pinto, E. J. A., & Maillard, P. (2019a). Uso de dados de radar altimétrico do satélite CRYOSAT para obtenção do perfil longitudinal do rio São Francisco. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Martins, M. A., Tomasella, J., & Dias, C. G. (2019b). Impacto das mudanças climáticas na produtividade e demanda hídrica do milho no Nordeste brasileiro. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Massing, J. M., Bartiko, D., Chagas, V. B. P., & Chaffe, P. L. B. (2019). Análise de tendências de vazões em usinas hidrelétricas no Brasil. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Matos, A. C. S., & Eleutério, J. C. (2019). Análise de perdas de vidas associadas à ruptura hipotética da Barragem de Fundão. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

McCabe, M. F., Rodell, M., Alsdorf, D. E., Miralles, D. G., Uijlenhoet, R., Wagner, W., Lucieer, A., Houborg, R., Verhoest, N. E. C., Franz, T. E., Shi, J., Gao, H., & Wood, E. F. (2017). The future of Earth observation in hydrology. *Hydrology and Earth System Sciences*, *21*(7), 3879-3914. PMid:30233123. http://dx.doi.org/10.5194/hess-21-3879-2017.

Medeiros, M. S., Santos, L. L., Paiva, R. C. D., Fleischmann, A. S., & Siqueira, V. A. (2019). Plataforma WEBGIS para visualização de dados hidrológicos observados e simulados na América do Sul. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Merriam, G. (1984). Connectivity: a fundamental ecological characteristic of landscape pattern. In J. Brandt & P. Agger (Eds.), *Proceedings of First International Seminar on Methodology in Landscape Ecology Research and Planning* (pp. 5-15). Denmark: Roskilde Universitessforlag GeoRue.

Meyer, A., Fleischmann, A., & Paiva, R. (2019). Como observações de sensoriamento remoto podem contribuir para a calibração de modelos hidrológicos. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Montanari, A., Young, G., Savenije, H. H. G., Hughes, D., Wagener, T., Ren, L. L., Koutsoyiannis, D., Cudennec, C., Toth, E., Grimaldi, S., Blöschl, G., Sivapalan, M., Beven, K., Gupta, H., Hipsey, M., Schaefli, B., Arheimer, B., Boegh, E., Schymanski, S. J., Di Baldassarre, G., Yu, B., Hubert, P., Huang, Y., Schumann, A., Post, D. A., Srinivasan, V., Harman, C., Thompson, S., Rogger, M., Viglione, A., McMillan, H., Characklis, G., Pang, Z., & Belyaev, V. (2013). "Panta Rhei – Everything Flows": change in hydrology and society: the IAHS scientific decade 2013-2022. *Hydrological Sciences Journal*, *58*(6), 1256-1275. http://dx.doi.org/10.1080/02626667.2013.809088.

Monte, B. E. O., Zanandrea, F., Abatti, B. H., Tavares, M. H., & Silveira, A. L. L. (2019). Capacidade do modelo HAND na representação de uma mancha de inundação comparado ao modelo hidrodinâmico HEC-RAS2D. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Monteiro, L. I. B., Souza, J. R. C., & Pruski, F. F. (2019). Dimensionamento de reservatório na bacia hidrográfica do rio Jequitinhonha sem e com a consideração da evaporação na superfície do lago. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Moreira, A. A., & Ruhoff, A. L. (2019). Padrões de evapotranspiração na Amazônia. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Moura, B. M. N. D., Cunha, A. H. F. D., & Fragoso Junior, C. R. (2019). Estimativa da temperatura de superfície da laguna mundaú por sensoriamento remoto aplicando um algoritmo de canal único. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Munar, A. M., Cavalcanti, J. R. A., Nascimento, G. D. S., Bravo, J. M., Ruhoff, A. L., Rodrigues, L. H. R., Marques, D. M. L. M., & Fragoso Junior, C. R. (2019). Dinâmica dos fluxos de calor na lagoa mirim acoplando modelagem hidrológica/hidrodinâmica, dados in situ e imagens MODIS LST. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Nagel, G. W., & Terra, F. S. (2019). Avaliação do índice de seca TVDI utilizando diferentes índices de vegetação para a estimativa da umidade do solo. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Naipal, V., Ciais, P., Wang, Y., Lauerwald, R., Guenet, B., & Van Oost, K. (2018). Global soil organic carbon removal by water erosion under climate change and land use change during AD-1850-2005. *Biogeosciences*, *15*(14), 4459-4480. http://dx.doi.org/10.5194/bg-15-4459-2018.

Nauditt, A., Johnsson, R. M. F., Hann, H., & Stahl, K. (2019). Avaliação do risco de seca em bacias hidrográficas rurais e tropicais com escassez de dados. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Nocko, H. R., & Cancelli, D. M. (2019). Modelagens matemáticas da hidrodinâmica e da qualidade da água do reservatório da UHE São Manoel. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Oliveira, D. Y., & Vrugt, J. A. (2019). Incerteza em assinaturas hidrológicas. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Oliveira, J. P. B., Cecílio, R. A., Pruskic, F. F., Zanetti, S. S., & Moreira, M. C. (2018). Assessing the use of rainfall synthetic series to estimate rainfall erosivity in Brazil. *Catena*, *171*, 327-336. http://dx.doi.org/10.1016/j.catena.2018.07.031.

Oliveira, G. G. D., Ruiz, L. F. C., & Quevedo, D. M. (2019a). Redes neurais artificiais e geotecnologias para o mapeamento de áreas suscetíveis a inundações. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Oliveira, H. R., Carvalho, A. V. V., Borges, M. M., & Silva, A. M. M. (2019b). Alocação negociada de água. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Oliveira, P. T. S., Almagro, A., Colman, C. B., Kobayashi, A. N. A., Rodrigues, D. B. B., Meira Neto, A. A., & Gupta, H. V. (2019c). Nexus of water-food-energy-ecosystem services in the Brazilian Cerrado. In R. C. Vieira da Silva, C. E. M. Tucci & C. A. Scott (Eds.), *Water and climate: modeling in large basins* (5th ed., pp. 7-30). Porto Alegre: ABRhidro.

Oliveira, W. L., Kaufmann, V., Torres, E., & Melo, M. N. V. (2019d). Análise da sensibilidade das variáveis para cálculo de descarga de sedimentos com o uso de metodologia de redes neurais artificiais. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Oliveira, P. T. S., Nearing, M. A., & Wendland, E. (2015). Orders of magnitude increase in soil erosion associated with land use change from native to cultivated vegetation in a Brazilian savannah environment. *Earth Surface Processes and Landforms*, *40*(11), 1524-1532. http://dx.doi.org/10.1002/esp.3738.

Oliveira, V. G., & Lima, C. H. R. (2016). Previsões multiescala de vazões para o sistema hidrelétrico brasileiro utilizando ponderação bayesiana de modelos (BMA). *RBRH*, *21*(3), 618-635. http://dx.doi.org/10.1590/2318-0331.011616032.

Ono, G. M., Mannich, M., Hilgert, S., & Bleninger, T. (2019). Estimativa da taxa de sedimentação com uso de armadilhas de sedimentos no reservatório Passaúna- PR. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Paixão, M., & Kobiyama, M. (2019). Sediment transport for nonuniform sediment mixtures: the Egiazaroff equation. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Palu, M. C., & Julien, P. Y. (2019). Modeling the sediment load of the Doce River after the Fundão Tailings Dam Collapse, Brazil. *Journal of Hydraulic Engineering*, *145*(5), 05019002. http://dx.doi.org/10.1061/(ASCE)HY.1943-7900.0001582.

Pandey, A., Himanshu, S. K., Mishra, S. K., & Singh, V. P. (2016). Physically based soil erosion and sediment yield models revisited. *Catena*, *147*, 595-620. http://dx.doi.org/10.1016/j.catena.2016.08.002.

Passaia, O. A., Paiva, R. C. D., & Brêda, J. P. L. F. (2019a). Análise exploratória do comportamento de reservatórios do Sistema Interligado Nacional. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Passaia, O. A., Siqueira, V. A., Brêda, J. P. L. F., Fleischmann, A. S., & Paiva, R. C. D. (2019b). Impacto de reservatórios em vazões simuladas por modelo hidrológico da América do Sul. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Pastor, A. V., Palazzo, A., Havlik, P., Biemans, H., Wada, Y., Obersteiner, M., Kabat, P., & Ludwig, F. (2019). The global nexus of food-trade-water sustaining environmental flows by 2050. *Nature Sustainability*, *2*(6), 499-507. http://dx.doi.org/10.1038/s41893-019-0287-1.

Paul, L. R., Abatti, B. H., & Michel, G. P. (2019). Análise de desempenho dos modelos SHALSTAB, SINMAP e TRIGRS para a avaliação da suscetibilidade a escorregamentos translacionais nas bacias Taboão e Matador, Rio do Sul (SC). In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Peixinho, F. C. (2019). Oferta hídrica no semiárido brasileiro. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Pereima, M. F. R., Amorim, P. B., Rodrigues, R. R., & Chaffe, P. L. B. (2019). Análise e correção de viés da precipitação de modelos de circulação geral do CMIP5 no Sul do Brasil. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Pereira, J. M. R., Santos, D. G., Vasconcelos Júnior, F. C., Fontenele, D. P., Martins, E. S. P. R., & Silveira, C. S. (2019). Avaliação das previsões subsazonais para as regiões homogêneas do estado do Ceará. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Petley, D. (2010). Landslide hazard. In I. Alcántara-Ayala & A. S. Goudie (Eds.). *Geomorphological hazard and disaster prevention* (pp. 63-73). Cambridge: Cambridge University Press. http://dx.doi.org/10.1017/CBO9780511807527.006.

Quedi, E. S., & Fan, F. M. (2019). Previsão hidrológica sub sazonal para a barragem de Itaipú, Brasil. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Quedi, E. S., & Fan, F. M. (2020). Sub seasonal streamflow forecast assessment at large-scale basins. *Journal of Hydrology*, *584*, 124635. http://dx.doi.org/10.1016/j.jhydrol.2020.124635.

Ramos, M. C. A., Pruski, F. F., & Ribeiro, R. B. (2019). Sazonalidade das vazões na cobrança pelo uso da água. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Rezende, T. N. D., & Bleninger, T. (2019). Interferência de dragagens na hidrodinâmica e salinidade de estuário. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Ribeiro, L. C., Andrade Neto, J. V., Cavalcante, T. L., Paiva, R. C. D., & Siqueira, V. A. (2019). Avaliação de vazões de referência estimadas a partir de modelagem hidrológica continental. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Riediger, P. I., & Marques, G. F. (2019). Qual o benefício econômico de antecipar a meta de enquadramento? Análise de caso no Jundiaí-SP. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Rossoni, R. B., & Fan, F. M. (2019a). A Hydrosedimentological Response Units map to South America. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Rossoni, R. B., & Fan, F. M. (2019b). Hydrological modelling parameters transfer of a Hydrosedimentological Response Units map. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Sá, J. H. M., Chaffe, P. L. B., & Quillet, M. J. J. (2016). The influence of the interception process on the precipitation quality in a catchment covered by subtropical Atlantic Forest. *Revista Brasileira de Recursos Hídricos*, *21*(4), 742-751. http://dx.doi.org/10.1590/2318-0331.011616045.

Sá, J. H. M., Oliveira, D. Y., Arienti, P. F., Alvarez Perez, A. B., Santos, C. I., & Chaffe, P. L. B. (2019). Variação do processo de interceptação durante eventos de precipitação em uma floresta ombrófila densa. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Sales, G. G. N., Bleninger, T., & Ishikawa, M. M. (2019). Aplicação do modelo GLM no reservatório do Passaúna. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Salvador, C. G., & Michel, G. P. (2019). Mapeamento de áreas suscetíveis a fluxo de detritos a partir de descritores da paisagem. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Santos, C. I., Perez, A. B. A., Sá, J. H. M., Arienti, P. F., & Chaffe, P. L. B. (2019a). Análise de padrões de isótopos da água no escoamento de base em uma bacia costeira. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Santos, L. L. D., Ruhoff, A. L., Fleischmann, A. S., & Kich, E. M. (2019b). Impactos das mudanças do uso da terra na evapotranspiração em área transicional entre os biomas Amazônia e Cerrado. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Santos, L. S., Carvalho, J. M., Degraf, H., & Fernandes, C. V. S. (2019c). Usinas hidrelétricas reversíveis no cenário brasileiro:

um estudo de caso. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Santos, M. S., & Lima, C. H. R. (2019). Análise de trajetórias de tempestades associadas a cheias máximas anuais no alto rio Paraguai. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Scortegagna, A. A., Sorribas, M. V., Lopes, M. S., Gonçalves, J. E., Da Paz, S. R., Inouye, R. T., Jusevicius, M. A., Areco, E. R., D'ávila, V. C., Leite, E. A., Beneti, C. A. A., Vilella, A. L. A., Mercanti, J. A., & Léo, E. C. (2019). Sistema de previsão hidrometeorológico para subsidiar a operação do Sistema Cantareira na gestão das bacias PCJ. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Sepúlveda, S. A., & Petley, D. N. (2015). Regional trends and controlling factors of fatal landslides in Latin America and the Caribbean. *Natural Hazards and Earth System Sciences*, *15*(8), 1821-1833. http://dx.doi.org/10.5194/nhess-15-1821-2015.

Silva, O. F. (2019). Implementação da política de recursos hídricos em comitês de bacias hidrográficas interestaduais: o papel político e a sustentabilidade financeira. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Silva, A. F. R., & Eleutério, J. C. (2019). Simulação de perdas de vidas causadas por inundações: modelos disponíveis e aplicações comparativas. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Silva, D. F., Pereira, T. A. S., Lima, S. G., Souza, J. F. S., & Vieira, A. S. (2019a). Análise de tendência em precipitações no sertão alagoano: estudo de caso do município de Delmiro Gouveia. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Silva, F. B., Almeida, L. T., Fraga, M. S., Ribeiro, R. B., Ramos, M. C. A., & Cecilio, R. A. (2019b). Análise do comportamento espectral da água do Rio Doce, Brasil, mediante o rompimento da barragem de sedimentos da empresa SAMARCO. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Silva, G. S., Moraes, M. M. G. A., & Silva, A. C. S. D. (2019c). HEAL - Um sistema de apoio a decisão espacial na alocação de água incorporando modelos hidro-econômicos. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Silva, M. L. R. S., Chan, C. S., Resende, N. C., Dereczynski, C. P., & Satyamurty, P. (2019d). Avaliação das simulações de precipitação subsazonais do modelo ETA para bacia do rio São Francisco. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Silva, R. A. G., Rosman, P. C. C., & Gallo, M. N. (2019e). Modelo numérico de processos hidrossedimentológicos em praias e próximo a obras hidráulicas marítimas. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Silva, S. B., Camargo Júnior, H., Rocha, V. F., & Torraca, H. B. B. (2019f). Avaliação do uso de dados de satélite para previsão de vazões utilizando o modelo hidrológico SMAP/ONS. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Silva, W. L., Maceira, M. E. P., & Rotunno Filho, O. C. (2019g). Tendências e projeções futuras de precipitação e de vazão nas Usinas Hidrelétricas de Tucuruí e Itaipu. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Silva, F. P., Rotunno Filho, O. C., Sampaio, R. J., Dragaud, I. C. D. V., Araújo, A. A. M., Silva, M. G. A. J., & Pires, G. D. (2019h). Evaluation of atmospheric thermodynamics and dynamics during heavy-rainfall and no-rainfall events in the metropolitan area of Rio de Janeiro, Brazil. *Meteorology and Atmospheric Physics*, *131*(3), 299-311. http://dx.doi.org/10.1007/s00703-017-0570-5.

Silvério, K. C., & Grimm, A. M. (2019). Impact of intraseasonal variability of Mozambique summer monsoon rainfall on water resources availability across the country. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Siqueira, V. A., Fan, F. M., Paiva, R. C. D., Ramos, M. H., & Collischonn, W. (2020). Potential skill of continental-scale, medium-range ensemble streamflow forecasts for flood prediction in South America. *Journal of Hydrology* , *590*, 125430. http://dx.doi.org/10.1016/j.jhydrol.2020.125430.

Siqueira, V. A., Weerts, A., Verkade, J., Klein, B., Fan, F. M., Paiva, R. C. D., & Collischonn, W. (2019). Melhorando o desempenho de previsões hidrológicas em escala continental através de pós-processamento. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Sivapalan, M., & Blöschl, G. (2017). The growth of hydrological understanding: technologies, ideas, and societal needs shape the field. *Water Resources Research*, *53*(10), 8137-8146. http://dx.doi.org/10.1002/2017WR021396.

Sivapalan, M., Takeuchi, K., Franks, S. W., Gupta, V. K., Karambiri, H., Lakshmi, V., Liang, X., McDONNELL, J. J., Mendiondo, E. M., O'Connell, P. E., Oki, T., Pomeroy, J. W., Schertzer, D., Uhlenbrook, S., & Zehe, E. (2003). IAHS Decade on Predictions in Ungauged Basins (PUB), 2003-2012: shaping an exciting future for the hydrological sciences. *Hydrological Sciences Journal*, *48*(6), 857-880. http://dx.doi.org/10.1623/hysj.48.6.857.51421.

Soares, L. M. V., Silva, T. F. G., Vinçon-Leite, B., Eleutério, J. C., Lima, L. C., & Nascimento, N. O. (2019). Modelling drought impacts on the hydrodynamics of a tropical water supply reservoir. *Inland Waters*, *9*(4), 422-437. http://dx.doi.org/10.1080/20442041.2019.1596015.

Sone, J. S., Gesualdo, G. C., Zamboni, P. A. P., Vieira, N. O. M., Mattos, T. S., Carvalho, G. A., Rodrigues, D. B. B., Alves Sobrinho, T., & Oliveira, P. T. S. (2019a). Water provisioning improvement through payment for ecosystem services. *The Science of the Total Environment*, *655*, 1197-1206. PMid:30577112. http://dx.doi.org/10.1016/j.scitotenv.2018.11.319.

Sone, J. S., Oliveira, P. T. S., Zamboni, P. A. P., Vieira, N. O. M., Carvalho, G. A., Araújo, A. R., Montagner, D. B., & Alves Sobrinho, T. (2019b). Effects of different land uses and soil management on soil erosion and water infiltration in an oxisol. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Souza, K. I. S. D., Chaffe, P. L. B., & Pinto, C. R. S. C. (2019a). Um software para a análise de seções transversais e de leitos fluviais regulares de rios do Brasil. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Souza, T. R. C., Rocha, C. A. D. F., Costa, R. A. M., Viana, E. M. F., & Martinez, C. B. (2019b). Proposta de metodologia de manutenção preditiva para sistemas de desassoreamento em PCH: estudo de caso usina de Furquim/MG. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

St. John, K., Bitting, K., Cervato, C., Kastens, K., Macdonald, R., McDaris, J., McNeal, K., Petcovic, H., Pyle, E., Riggs, E., Ryker, K., Semken, S., & Teasdale, R. (2019). An evolutionary leap in how we teach geosciences. *Eos*, *100*. http://dx.doi.org/10.1029/2019EO127285.

Subira, D., & Bueno, A. S. (2019). Automação e controle das válvulas de descarga da barragem Pedro Beicht: uso da energia limpa e da tecnologia para redução de perdas. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Sumi, T., & Hirose, T. (2009). *Accumulation of sediment in reservoirs: water storage, transport and distribution* (pp. 224-252). Paris: UNESCO-IHE and EOLSS Publishers Co. Ltd.

Taffarello, D., Souza, F. A. A., Mendiondo, M., Oliveira, V. G., & Mendiondo, E. M. (2019). Água, serviços ecossistêmicos e psique humana: conexões iniciais para uma emergente sociohidrologia. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Tauro, F., Selker, J., Van de Giesen, N., Abrate, T., Uijlenhoet, R., Porfiri, M., Manfreda, S., Caylor, K., Moramarco, T., Benveniste, J., Ciraolo, G., Estes, L., Domeneghetti, A., Perks, M. T., Corbari, C., Rabiei, E., Ravazzani, G., Bogena, H., Harfouche, A., Brocca, L., Maltese, A., Wickert, A., Tarpanelli, A., Good, S., Lopez Alcala, J. M., Petroselli, A., Cudennec, C., Blume, T., Hut, R., & Grimaldi, S. (2018). Measurements and Observations in the XXI century (MOXXI): innovation and multidisciplinarity to sense the hydrological cycle. *Hydrological Sciences Journal*, *63*(2), 169-196. http://dx.doi.org/10.1080/02626667.2017.1420191.

Tavares, M. H., Marques, D. M. L. M., & Fragoso Junior, C. R. (2019). Combinando modelo de temperatura da água e sensoriamento remoto para estimar o efeito da mudança climática sobre a temperatura da lagoa Mangueira-RS. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Tomasella, J., & Cunha, A. P. M. A. (2019). Análise comparativa de índices de seca operacionais para o nordeste brasileiro. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Torres, C. J. F., Fontes, A. S., Goodwin, B. S. A., Ribeiro, D. V., & Medeiros, Y. D. P. (2019a). NEXUS energia - agricultura - ecossistema: uma proposta para apoio na definição de ações de mitigação de impactos nos ecossistemas. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Torres, C. J. F., Silva, R. S. X., Basto, I. D. R. G., Fontes, A. S., Ribeiro, D. V., & Medeiros, Y. D. P. (2019b). Teoria dos NEXUS como planejamento estratégico para a alocação de água. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Treistman, F., Maceira, M. E. P., Penna, D. D. J., & Rotunno Filho, O. C. (2019). Análise da influência do fenômeno El Niño - oscilação sul nas vazões naturais afluentes à usinas hidroelétricas brasileiras. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Troch, P. A., Lahmers, T., Meira, A., Mukherjee, R., Pedersen, J. W., Roy, T., & Valdés‐Pineda, R. (2015). Catchment coevolution: a useful framework for improving predictions of hydrological change? *Water Resources Research*, *51*(7), 4903-4922. http://dx.doi.org/10.1002/2015WR017032.

Tschiedel, A. F., Fan, F. M., Paiva, R. C. D., & Tassinari, L. C. S. (2019). Barragens e rompimentos: compilação histórica nacional e internacional. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

United Nations Educational, Scientific and Cultural Organization – UNESCO. (2019). *Intergovernmental hydrological programme (IHP)*. Retrieved in 2019, October 17, from https://es.unesco.org/themes/garantizar-suministro-agua/hidrologia

United Nations Office for Disaster Risk Reduction – UNISDR. (2015). *Making development sustainable: the future of disaster risk management: global assessment report on disaster risk reduction*. Geneva: UNISDR.

Universidade Federal de Santa Catarina – UFSC. Centro Universitário de Estudos e Pesquisas sobre Desastres – CEPED. (2013). *Atlas brasileiro de desastres naturais: 1991 a 2012* (2. ed. rev. ampl.). Florianópolis: CEPED/UFSC.

Urzulin, T. A., Cestari Junior, E., Braga, R. S., & OLIVEIRA, P. D. (2019). Estudos para revisão da restrição de vazão máxima da UHE Jupiá: em busca de mais segurança e economicidade no atendimento. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523-538. PMid:20585380. http://dx.doi.org/10.1007/s11192-009-0146-3.

Vanelli, F. M., & Kobiyama, M. (2019). Situação atual da socio-hidrologia no mundo e no Brasil. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Vanelli, F. M., Kobiyama, M., Fan, F. M., & Goldenfum, J. A. (2019). Como aprender mais com as grandes inundações ocorridas? In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Vargas, M. M., Beskow, S., Caldeira, T. L., Corrêa, L. L., & Cunha, Z. A. (2019). SYHDA: System of Hydrological Data Acquisition and Analysis. *Revista Brasileira de Recursos Hídricos*, *24*, e11. http://dx.doi.org/10.1590/2318-0331.241920180152.

Vasconcellos, S. M., & Kobiyama, M. (2019). Análise do perigo de inundação nos leques aluviais da bacia do alto Mampituba RS/SC. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Vásquez, P. I. L., Araujo, L. M. N., Molion, L. C. B., Abdalad, M. A., Moreira, D. M., Sanchez, A., Barbosa, H. A., & Rotunno, O. C. (2018). Historical analysis of interannual rainfall variability and trends in southeastern Brazil based on observational and remotely sensed data. *Climate Dynamics*, *50*(3-4), 801-824. http://dx.doi.org/10.1007/s00382-017-3642-9.

Venzon, P. T., Montagna, T., Horn, P. A., Vieira, P. B. H. G., & Pinheiro, A. (2019). Modelagem dinâmica da regeneração vegetativa na paisagem inundada pela onda de rejeitos em Mariana - MG. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Vichete, W. D., & Mello Júnior, A. V. (2019). Modelo hidro-econômico de alocação de água nos reservatórios do Sistema Cantareira. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Villela, E. C., & Kobiyama, M. (2019). Reconstrução e análise de um fluxo de detritos por meio de dados de campo e do modelo KANAKO-2D no município de Gaspar/SC. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Werlang, M. M., Rivarola Sosa, J. M., Villa Trinidad, G. G., Quevedo Aguade, J. M., Zaicovski, M. B., Kazay, D. F., Aguero, T. M. I. V., Fariña Jara, M. J. M., & Takahashi, R. H. (2019). Metodologia de cálculo da vazão afluente consistida ao reservatório de Itaipu. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

White, D. D., Lawless, K. L., Vivoni, E. R., Mascaro, G., Pahle, R., Kumar, I., Coli, P., Castillo, R. M., Moreda, F., & Asfora, M. C. (2018). Co-producing interdisciplinary knowledge and action for sustainable water governance: lessons from the development of a water resources decision support system in Pernambuco, Brazil. *Global Challenges*, *3*(4), 1800012. PMid:31565371. http://dx.doi.org/10.1002/gch2.201800012.

Wiegand, M. C., Lima Neto, I. E., & Costa, A. C. (2019). Avaliação quantitativa e predição de dominância de cianobactérias em reservatórios semiáridos. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Winton, R. S., Calamita, E., & Wehrli, B. (2019). Reviews and syntheses: dams, water quality and tropical reservoir stratification. *Biogeosciences*, *16*(8), 1657-1671. http://dx.doi.org/10.5194/bg-16-1657-2019.

Wohl, E. (2017). Connectivity in rivers. *Progress in Physical Geography: Earth and Environment*, *41*(3), 345-362. http://dx.doi.org/10.1177/0309133317714972.

Wongchuig, S. C., Paiva, R. C. D., Siqueira, V., & Collischonn, W. (2019). Hydrological reanalysis across the 20th century: a case study of the Amazon Basin. *Journal of Hydrology*, *570*, 755-773. http://dx.doi.org/10.1016/j.jhydrol.2019.01.025.

World Meteorological Organization – WMO, Global Framework for Climate Services – GFCS. (2016). *Climate services for supporting climate change adaptation: supplement to the technical guidelines for the national adaptation plan process*. Geneva: WMO/GFCS.

Zanandrea, F., Biehl, A., Michel, G. P., & Kobiyama, M. (2019). Relação entre áreas suscetíveis a escorregamentos e conectividade de sedimentos. In *Proceedings of the XXIII SBRH 2019*. Porto Alegre: ABRH.

Zanandrea, F., Paul, L. R., Michel, G. P., Kobiyama, M., Zanini, A. S., & Abatti, B. H. (2020). Conectividade dos sedimentos: conceitos, princípios e aplicações. *Revista Brasileira de Geomorfologia*, *21*(2), 435-459. http://dx.doi.org/10.20502/rbg.v21i2.1754.

Zingaro, M., Refice, A., Giachetta, E., D'Addabbo, A., Lovergine, F., Pasquale, V., Pepe, G., Brandolini, P., Cevasco, A., & Capolongo, D. (2019). Sediment mobility and connectivity in a catchment: a new mapping approach. *The Science of the Total Environment*, *672*, 763-775. PMid:30974366. http://dx.doi.org/10.1016/j.scitotenv.2019.03.461.

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