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GEWEX is a Core Project of the World Climate Research Programme on Global Energy and Water Exchanges

What Lies Ahead for Global Water Futures

A high-alpine meteorological observation station at Helen Creek in Banff National Park, Alberta in the Canadian Rocky Mountains, part of the GWFO project. See Pomeroy, Schuster-Wallace, and DeBeer on pg. 16 for more.

Inside This Edition

Partnership between Space Agencies and GEWEX

Xubin Zeng
Co-Chair, GEWEX Scientific Steering Group

One of the reasons for the success of GEWEX for more than three decades is its close connection with space agencies, particularly those in the U.S., Europe, and Japan. This is the right time to re-imagine this partnership for two reasons: a) inflation and supply chain issues have significantly increased satellite mission costs, suggesting the critical importance of international collaboration and cooperation; and b) several other countries (e.g., China, India, Brazil, South Korea) have developed robust Earth science space programs in recent years, and even more countries are pursuing space programs through cubesats and smallsats. Here are my perspectives on this new partnership.

GEWEX should act as a bridge to bring together all space programs for water and climate science and applications. One way is to invite new space agencies and associated scientists to prepare short news articles on satellite mission planning and open data access for the *GEWEX Quarterly*. Another way is to organize space agency roundtables during major GEWEX conferences (e.g., the Open Science Conference in Japan in July 2024) and/or during the annual Scientific Steering Group meetings.

Satellite remote sensing data are invaluable in addressing scientific questions [e.g., as emphasized by the National Aeronautics and Space Administration (NASA)], in improving numerical weather prediction, and in a variety of other applications (e.g., disaster reduction, aviation, agriculture, water resources, public health). A key gap in realizing the full potential of satellite data in addressing climate change is the support and planning of continuity missions. A synergy can be provided through international coordination, with individual space agencies focusing on the continuity of a small number of missions. To benefit all countries and the science and applications community, open data policy and open science are required.

Related to satellite remote sensing, suborbital missions (or airborne field campaigns) have been widely used for satellite measurement calibration and validation and for addressing science questions. In contrast to the gridded data provided by the satellite missions that are generally user-friendly, the use of airborne data is much more limited for users who are not involved in field campaigns. Innovations are needed to make airborne data easy to use; e.g., by developing airborne gridded data.

There is a perception that there were more available satellite data than the (coarse-resolution) global models could use in the past, but now the kilometer-scale regional and global models don't have enough satellite data at the relevant spatial and temporal resolutions. Therefore, it is particularly important to develop 5-km, 30-minute, 3-D cloud data through the GEWEX Next Generation International Satellite Cloud Climatology Project (ISCCP-NG).

For existing satellites, the synergistic use of all available satellite and surface-based measurements and computer models to study the energy, water, and carbon cycles should continue to be supported as interdisciplinary team efforts by various space agencies; e.g., through the NASA Energy and Water Cycle Study (NEWS) program. For instance, the newly launched Surface Water and Ocean Topography (SWOT) mission provides exciting opportunities to quantify and understand the water cycle at river basin and subbasin scales by combining its global measurements of water levels of rivers and lakes and inundation extents with other measurements such as precipitation, soil moisture, terrestrial water storage, river discharge, groundwater, and evaporation.

For future missions, innovation is needed for satellite measurements of snowfall and snow water equivalent. This is important not only for the study of the global water cycle as emphasized by GEWEX, but also for the Global Precipitation EXperiment (GPEX), the new WCRP Lighthouse Activity. Further, recognizing the coupling between water and carbon cycles and the international goal in reaching net-zero emissions, satellite measurements of atmospheric greenhouse gases are urgently needed. As horizontal transport represents the largest uncertainty in reconciling these measurements and surface-based emission estimates (e.g., as reported by individual countries), the satellite measurement of 3-D distribution of horizontal wind by combining active and passive remote sensing is also needed.

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New GEWEX Panel Members

Paola A. Arias, the new GEWEX Hydroclimatology Panel (GHP) Co-Chair, is a full professor at the Environmental School at the Engineering Faculty in Universidad de Antioquia - Colombia. Her research focuses on climate variability and change in northern South America, including the analysis and simulation of extreme precipitation and drought events as well as the impacts of land cover changes (deforestation). She is a member of the Scientific Development Team of the WCRP My Climate Risk Lighthouse Activity. She is Lead Author of the IPCC WGI AR6 Chapter 8, focused on water cycle changes. She is also Coordinating Author of the AR6 WGI Technical Summary, Summary for Policy Makers, and Annex V on Monsoons. In addition, she is Review Editor of the AR6 Synthesis Report.

Philip Stier is a Professor of Atmospheric Physics at the University of Oxford and a new member of the Global Atmospheric System Studies (GASS) Panel. Philip's research topics cover physical aspects of the climate system, with a focus on clouds, aerosols, and radiation. Philip has co-led the GEWEX Aerosol Precipitation (GAP) initiative with Sue van den Heever (CSU) since 2017. His research combines global and high-resolution modeling, remote sensing, and in situ observations, as well as machine learning to constrain clouds, aerosols, and their complex interactions to gain insights in their effects on climate. Philip's group is embracing the opportunities provided by the emergence of global km-scale modeling and is actively working on constraining these models combining time-resolved satellite data sets with cloud tracking and machine learning.

Dr. Patrick Taylor, a research scientist at National Aeronautics and Space Administration (NASA) Langley Research Center and member of the Radiation Budget Science Project, is joining the GEWEX Data and Analysis Panel (GDAP). His research focuses on using satellite, airborne, and surface data synergistically with models to understand the role of clouds within the global climate system. Dr. Taylor's recent work has focused on advancing knowledge of the Arctic climate, including the causes of rapid Arctic climate change; the process drivers of Arctic Amplification and the factors contributing to the uncertainty in Arctic climate projections, the linkages between the Arctic and lower latitudes; cloud-sea ice interactions; and the interactions between the sea ice properties and the Arctic surface energy budget. Dr. Taylor is also a member of the Group of Earth Observations (GEO) Climate Change Working Group and Deputy Science Lead for the NASA Arctic Radiation-Cloud-Aerosol-Surface Interaction eXperiment (ARCSIX) to be held in summer 2024.

Dr. Brent Roberts, a research scientist with the National Aeronautics and Space Administration (NASA) Marshall Space Flight Center (MSFC), is joining the GEWEX Data and Analysis Panel (GDAP). At MSFC, he led activities supporting numerous NASA research programs investigating global to regional energy and water cycle variability, developing fundamental climate data records of ocean evaporation, and examining observed atmosphere-ocean variability and its representation in Earth modeling systems. He has also served as the Weather and Climate Resilience thematic lead for the joint NASA-USAID (United States Agency for International Development) SERVIR program to co-develop and coordinate the application of Earth observations to address societal needs in countries across Asia, Africa, and Latin America. He is looking forward to bringing his previous experience supporting GEWEX projects to advance our theoretical, observation, and model-based understanding of global energy and water cycle variability and its impact on communities.

Dr. Vimal Mishra, currently a professor in Civil Engineering and Earth Sciences at Indian Institute of Technology Gandhinagar, is one of the new the GLASS Panel members. Prior to joining IIT Gandhinagar, he completed his Ph.D. from Purdue University and postdoctoral fellowship from University of Washington, Seattle. Dr. Mishra's research focuses on large scale hydrological modeling, remote sensing, and climate change impact assessment. He is a fellow of the American Geophysical Union (AGU) and the National Academy of Sciences, India (NASI). He is currently serving as an editor of Earth's Future and associate editor of *Journal of Hydrology*.

Dr. Marina Hirota, currently an associate professor of Meteorology at the Federal University of Santa Catarina (Brazil), has built up her academic career through a very interdisciplinary background. Such variety defined her current research field in Earth System Sciences, more specifically, trying to understand the processes and interactions involved in biome shifts within tropical zones, using dynamical system concepts such as resilience, tipping points and hysteresis. She is particularly focused on searching for multi-scale and synergistic mechanisms within atmosphere-biosphere interactions to deepen both quantitatively and qualitatively the scientific basis of tipping points in South American tropical ecosystems. Participating on the GLASS Panel comes at a timely moment, given that she is aiming at improving the representation of tropical biodiversity in land surface models to better qualify and quantify the resilience of tropical ecosystems to current and future environmental changes.

H3S Summer Highlights: Resources and Webinars for Early Career Researchers

Danyka Byrnes[1], Paige Becker[2], and Emily Ellis[3]
On behalf of the American Geophysical Union Hydrology Section Student Subcommittee (AGU-H3S)
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As the year hurtles forward with breathtaking speed, it's hard to believe another academic term has ended and the next is approaching. Many of us have returned to our field sites for the much-anticipated field season. Those of us whose work is computer-based probably have our windows cracked, appreciating the quiet of the campus or office space. While many of the H3S committee is out in the wild, that doesn't mean we've left our community behind. Recognizing the importance of fostering a community and resources for early career researchers, we have been working to deliver some great content to our community!

New Blog Posts

The past few months have been full of great new blog posts by the members of H3S covering topics from approaching science as a team, to research skills, to professional development:

- *Essential Resources for Team Science Success* by Delaney Peterson
- *The Meandering River of Data-Driven Research: The Underappreciated Skill of Looking for Datasets* by Seth Adelsperger and Danyka Byrnes
- *Insights and Tips for International Graduate Students* by Soumaya Nabih

Seminar Series Dates Announced

H3S aims to bring together panels of experts to exchange ideas, share insights, and help us early career scientists grow!

Coming this fall, H3S and the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) will be hosting the webinar series "Navigating Academic Waters" (*https://tinyurl.com/H3SFindingYourNiche*). Each event will occur from 1:00-2:00 PM EST and have a paired panel discussion with a co-working session the following week.

- Where to Go from Here: Narrowing Your Professional Path
  September 14, 2023 & September 21, 2023
- The What, Why, and How of Building Your Personal Research Brand
  October 12, 2023 & October 19, 2023
- Building Support: Developing Effective Mentoring Relationships
  November 9, 2023 & November 16, 2023

Follow us on our social media channels or subscribe to our newsletter on our website (*agu-h3s.org*) for further details and registration links: Twitter (*twitter.com/AGU_H3S*), Facebook (*tinyurl.com/h3s-faceb*), and LinkedIn (*tinyurl.com/h3s-linkedin*).

YESS Community Involvement in International Science Meetings

Faten Attig Bahar[1], Gerbrand Koren[2], Javed Ali[3], and the YESS Executive Committee
[1]University of Carthage, Tunisia Polytechnic School, Al Marsa, Tunis, Tunisia; [2]Copernicus Institute of Sustainable Development, Utrecht University, Utrecht, The Netherlands; [3]Department of Civil, Environmental, and Construction Engineering & National Center for Integrated Coastal Research, University of Central Florida, Orlando, FL, USA

YESS at WCRP JSC: YESS was invited by the World Climate Research Programme Joint Scientific Committee (WCRP JSC) to participate in its annual meeting (*https://www.wcrp-climate.org/jsc44*), which took place between May 8th and 11th in Brussels, Belgium. ExeCom member Faten Attig Bahar and YESS Officer Valentina Rabanal represented YESS Community activities and progress. We would like to thank WCRP for its continuous support of the YESS Community.

YESS at SRI 2023: YESS is proudly looking back on its participation at the Future Earth and the Belmont Forum Sustainability Research and Innovation Congress (SRI2023) Africa Satellite Event (*https://sricongress.org/sri2023-africa-satellite-event/*). Our ExeCom member Faten Attig Bahar co-chaired the organizing team of the first edition of SRI2023 Africa, held from June 20th to June 22nd at the University of Nelson Mandela in Port Elizabeth, South Africa, hosted by the Future Earth Africa Hub and the National Research Foundation (NRF). SRI2023 Africa brought together 320 participants from different parts of Africa who contributed to the rich conference program. Moreover, alongside the event, Faten chaired the ECRs corner, composed of four ECR sessions and one training workshop on scientific writing for sustainability research that benefited several young researchers and scientists from all over Africa.

YESS at the WCRP OSC: YESS is delighted to host Townhall #3 and TownHall #9 at the upcoming WCRP Open Science Conference (OSC, *https://wcrp-osc2023.org/*). In Townhall #3, the discussion will explore specific issues about the Global South-Global North equitable partnership and reflect on actions allowing us to bridge the gaps, and during TownHall #9, YESS will host a community discussion on the challenge of balancing data-intensive activities. We aim for an inter-generational and interactive dialogue, inviting early- to mid-career and established researchers to attend this meeting.

YESS at AGU Fall Meeting 2023: YESS ExeCom member Javed Ali will be co-convening a Town Hall at the American Geophysical Union (AGU) Fall Meeting 2023, to be held in San Francisco, USA. The session, titled "Building your Network - Sharpening the Soft Skills of Science" (*https://agu.confex.com/agu/fm23/prelim.cgi/Session/187201*), is geared towards early-career and student scientists who aim to advance their soft skills beyond the conventional classroom or laboratory learning and offer valuable insights into mastering essential soft skills such as effective communication, time management, and interpersonal relationships within both industry and academia.

Enhancing the Actionability of GEWEX Projects: Designing Responsible and Collaborative Processes

Monica Ainhorn Morrison
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The Challenge of Actionable Knowledge

A decade ago, the climate science community began to recognize a gap between the generation of climate information and its use by those in societal spaces, including policy makers, regional and local managers, and communities looking for adaptation and resilience guidance (Lemos et al., 2012). The gap between production and use was surprising considering the large amount of climate research that made its way across the boundary between science and society, and the increasing demand for information. Studies that followed this realization called on more intentional collaboration between those on both sides of the boundary to increase the usability of climate research products, often citing a need to shift systems of knowledge to being more use-inspired and demand-driven.

Despite a vast number of articles published since attention was brought to this issue, recent studies have revealed that there still exists a considerable gap (Daly, 2021). Reasons for the sustainment of this challenge relate to an overwhelming focus on the generation of higher quality products for use as opposed to the processes by which actionable knowledge is generated, the employment of assumptions about criteria for usefulness and usability of products by researchers, and a systematic lack of evaluation of outcomes of those projects and systematic identification of the drivers and challenges in relation to the successful uptake and outcomes of co-produced research (Findlater et al., 2021).

Hence, there exists a need for those science programs aimed at generating more actionable information to focus on the design and implementation of processes for effective co-production of climate information, and to support the evaluation of the outcomes of these processes. The benefit of having projects aimed at process design, implementation, and evaluation is the increased probability of achieving actionable science goals and the intentional development of a network of sustainable science-society partnerships.

The Logics and Pragmatics of Actionable Knowledge

Actionable knowledge has widely been defined as knowledge that is fit for use in a decision-making context, or the ability of information to effectively inform decisions (Arnott et al., 2020; Beier et al., 2017). A more detailed understanding of the concept breaks down actionable knowledge into 1) criteria for actionable products, and 2) conditions governing processes for the generation of actionable products. In short, the products must both be adequate and usable.

The former refers to the quality of the information and its adequacy in terms of its relationship to the problem or question and the use purpose. At its most basic level, the adequacy of a product for a specific purpose is defined in terms of its reliability in a type of use. A product can be deemed adequate for a purpose when in the context of interest; i.e., context of use or problem, the purpose, or goal of the use of the information, is likely to be achieved both epistemically and pragmatically (Parker, 2020). Different sources and forms of information can be more or less appropriate for use in different contexts, with some contexts requiring multiple types of information joined together to serve the particular purpose (Doblas-Reyes et al., 2021). The failure of a product to meet the conditions of adequacy for its particular purposes, whether actionable or not, results in the introduction of risks of information inaccuracy, irrelevance, incompleteness, or misleading results (Harvard and Winsberg, 2022). These can lead to the presence of hazards when the information is used to make decisions, and might manifest as downstream harm, such as the misallocation of limited resources or maladaptation (Morrison, 2023).

Usability focuses on whether the knowledge product is further consistent with the application context in terms of its reflection of the social, political, cultural, and economic dimensions of that context. Much work has been done to detail the conditions for product usability in the literature, with most attention being given to the importance of the product being perceived by users as credible, salient, and legitimate (Cash et al., 2003). Credibility is especially important with respect to the users' perception of the adequacy of the evidence and inferences made in the construction of the solution and can increase their trust in the accuracy of information. Salience relates the relevance of the information to the needs and priorities of the users, whereas legitimacy focuses mainly on the process for information production and its perception as fair, impartial, and respectful of divergent values and belief systems. These features of usability are intimately connected, but have also been found to require tradeoffs, such that higher credibility might mean less salience or legitimacy (Cash et al., 2002).

Processes for generating actionable science, detailed more in the section below, must be inclusive, collaborative, and flexible (Vincent et al., 2018). The iterative, two-way nature of the required process marks a departure from the traditional "push" of scientific information from the research context out into society. The collaborative elements of the process exist through the entire lifecycle of the research process, from the identification of the problem or question, decisions about methods and approaches, to the development and delivery of an "answer" or solution. The Intergovernmental Panel on Climate Change (IPCC) Working Group I (WG1) notes that partnerships, and collaboration, across all elements and parties involved in the production, exploration, and distillation of climate information are at the center of producing actionable climate information (Doblas-Reyes et al., 2021).

Designing an Effective and Responsible Process

Coproduction has been highlighted as the model for meeting the above product criteria and process conditions of inclusivity, flexibility, and collaboration. However, there is no

single model for coproduction that exists—the process has significant potential, but there are a variety of processes that might be included under the concept of coproduction, and what counts as coproduction can vary across contexts. The most general definition is a collaborative process of knowledge production that involves multiple disciplines and community partners from a variety of sectors (Pohl, 2008).

But coproduction, and integration of different viewpoints on research problems and solutions, is not easy. The process most likely will require some degree of integration between the scientific perspective and the user perspective, both of which are influenced by contextual factors. The process has a high possibility of experiencing challenges related to differences in culture, institutional contexts, resource limitations, gaps between scales of available research and user information needs, and diversity of priorities across collections of community partners. There is also an implicit need, which can go unrecognized, to co-develop rules, norms, and practices for the successful and equitable interactions between science and society (Cash and Belloy, 2020).

This marks the central challenge with designing processes for successful coproduction of actionable science, and where a gap in our conceptual knowledge currently exists: the lack of understanding of how the different features of a particular context can influence the development and use of information, despite a clear awareness that the context can impose considerable constraints on how information is produced and able to serve a particular application (Doblas-Reyes et al., 2021). When designing a plan for the generation of actionable knowledge, there is a need to identify and describe the features of the use context that are actively impacting knowledge production and use. This context of use will include cultural, institutional, political, socioeconomic, and epistemic/belief factors that determine the conditions under which knowledge will be the accepted and employed in decisions on how to adapt and develop resilience, or manage climate impacts more generally (Dilling et al., 2015).

Even the more "passive" processes for enhancing usability, such as the translation of research, requires a keen understanding of the use context, such that awareness of conceptual and value "languages", cultures, and socio-political institutions is required for successful practice (Enquist et al., 2017). Hence, the challenges that face coproduction and its success are also shared by those less collaboration-intensive activities where the concern is not to have end-to-end involvement by users, but rather to fit existing research findings into a decision-making context through novel interpretation and presentation approaches.

Some studies have cited the success of coproduction through the use of boundary agents, who operate as the personal bridge between the researchers and societal users. Leveraging boundary agents, who are experts or highly competent in the science, but also have existing connections to communities, can help to avoid the need for formal institutional arrangements, facilitate communication and translation, and aid in mediating across the diversity of interests of the parties involved in coproduction (Jagannathan et al., 2021). Organizations—such as national climate service institutions—can also facilitate processes, and are better able to address the varied needs of complex societal community populations who might integrate scientific information into their decision processes (Doblas-Reyes et al., 2021). Starting with the design of boundary objects has also proven successful in some cases; for example, with the co-design of metrics for management of climate impacts in the United States. Co-designed metrics can function as the interface between climate researchers and societal users by allowing for iterative mediation of disparate interpretations of climate problems and the type of information needed to inform solutions (Reed et al., 2022). They have the added benefit of providing an object to synthesize the assessment of the adequacy of a product as well as its context relevance, or fitness, for a specific purpose.

Coproduction provides an incredibly promising approach of increasing the actionability of research products, but work is required to properly map out the details of the context in which the coproduction will be undertaken, so that effective and responsible processes can be implemented.

The Importance of Context and Values

Recently, philosophers of science and IPCC WGI have pointed to the importance of developing an awareness of the role of values in research and information dissemination about climate change, and the need to manage the influence of values inconsistent with users' interests (Doblas-Reyes et al., 2021). Values are involved in all aspects of the scientific process, from the generation of research problems and questions, the evaluation of evidence and models, to the communication and translation of results (Pulkkinen et al., 2022). The utility of having awareness of how values enter into research decisions is that we can manage the way unacknowledged assumptions might introduce barriers to knowledge use and uptake. When thinking about actionable science and the process of coproduction, these barriers can be best managed by developing an awareness of key decision points in the coproductive processes, and with that, an awareness of how values might influence the outcomes of these decisions. We want to ensure, not only for the sake of successful adoption of research outcomes, but also for the sake of just science, that the choices being made in the course of research are prioritizing, and consequentially benefiting, the interests of the users as opposed to those of the information producers. This can be achieved, for example, by thinking not only about what users of information want to know, but also about the types of errors they might seek to avoid in choices about climate data information sources, the building of impacts models, analysis methods for data and model results, and in the estimation of uncertainties (Parker and Lusk, 2019).

Designs for coproduction processes can explicitly identify these potential challenges and provide guidance on how to ensure that uncertain methodological choices are reflections of the user's perception of the lower risk of a particularly undesirable error in the outcomes (e.g., the over- versus underestimation of prolonged periods of drought for reservoir managers).

Why GEWEX?

While not all of the research conducted in GEWEX is purposed to be actionable, there are two features that make some

of its projects especially well-suited to engage in research to 1) investigate contexts of hydroclimate knowledge use and 2) design, implement, and evaluate the potential of various processes, involving coproduction and its mechanisms, to increase the actionability of certain research output. The first is an explicit goal of many of the projects, to engage and involve stakeholders for the sake of creating scientific frameworks and products that contribute to decision making around adaptation, resilience, and sustainability. In particular, many aspects of the GEWEX Hydroclimatology Panel (GHP) Regional Hydroclimate Projects (RHPs) are oriented towards providing regionally-based scientists with the knowledge and methods necessary to utilize portions of GEWEX information and enhance their abilities to contribute knowledge to policy, management, and community stakeholders. Baltic Earth has established itself not only as a program that bridges gaps between disparate research communities, but also as a network capable of communicating and engaging with stakeholder communities to ensure that research products are influential and relevant.

The GEWEX program also has an explicit commitment to capacity building within the research and impacted communities, which is a fundamental component to developing a sustained network of researchers, practitioners, and community partners. Studies have commented on the increase in potential for success in coproduction when there are existing networks and relationships that can be leveraged in the generation of actionable knowledge products (Vogel et al., 2016). The capacity building activities have been oriented toward the building of knowledge networks that not only bridge gaps between research communities, but also those who are the producers and users of the research. Baltic Earth has hosted an extensive collection of workshops to foster international research community relations and build capacity through developing relations with stakeholders, i.e., in workshops directed at bringing regional stakeholder groups together such as with the Baltic Sea Science Congress of 2021, and then the Baltic Stakeholder Conference of 2022.

This makes several of the existing networks and projects' components well suited to collaborate on the designing of processes and mechanisms based on past experiences, and provides potential through not yet developed, but planned, networks to test out the effectiveness and feasibility of the designed mechanisms. Hence, these already-existing networks and new initiatives can be leveraged to provide a foundation for facilitating the development of a framework for actionable knowledge generation through coproductive processes and mechanisms. Hence, the proposal for this Crosscutting Project is not only consistent with the goals of several GEWEX projects and initiatives, but also contributes to enhancing the capacity building goals of the program.

A Proposal: A Crosscutting GHP Project

I propose a Crosscutting Project aimed at investigating, designing, implementing, and evaluating processes related to coproduction for the enhanced actionability of GEWEX research products. This effort will be undertaken in collaboration with the existing network of researchers connected to communities in different regions by way of the RHPs. A project with these objectives can aid in: 1) the understanding of how context influences the production and use of climate information; 2) the development of an informed framework for how to go about generating adequate and usable knowledge for hydroclimate adaptation, resilience, and sustainability; and 3) providing guidance on best practices for how to fit research to user information needs within GEWEX RHPs, particularly through the development and use of boundary objects to serve as effective bridges between communities.

The project will serve as the starting point for developing concrete solutions to the challenges related to the uptake of scientific research products and the transformation of hydroclimate knowledge into action and innovation. Furthermore, well-informed plans for the coproduction of research that are aware of the importance of context are key to engaging with local scientists and decision makers in those countries and communities that have been historically scientifically marginalized and are increasingly vulnerable to hydroclimatic changes, and that GEWEX seeks to connect with.

This project is best suited for treatment as a Crosscutting Project as there are specific questions to be addressed within an RHP's focus related to the methods and approaches for doing science that has societal relevance, and these questions offer a general set of challenges that fosters collaboration and interaction between the individual RHPs as well as broader GEWEX and World Climate Research Programme (WCRP) activities. Of particular interest would be collaborative possibilities between RHP projects such as ANDEX and the related WCRP Lighthouse Activity My Climate Risk Regional Hub for South America, which is also explicitly focused on approaching assessments of regional climate risk through co-production with stakeholders. Moreover, RHPs such as Baltic Earth and Global Water Futures have been active in engaging stakeholders and experimenting with processes for the generation of actionable information and use of boundary objects. Although these products, objects, and processes are contextual, they present an opportunity to learn from past experiences about successes and challenges. Presumably, a close study with GHP leaders can provide a foundation for understanding features of successful endeavors, and aid in the designing of new coproduction practices to test in the context of initiated projects, such as ANDEX. I propose we begin with a systematic identification and study of those boundary objects that have proven successful and might have global import from Global Water Futures and Baltic Earth. This can be used to design and implement, through a series of small-scale tests of different concepts, approaches, and practices, an intentional and strategic process for enhancing the adequacy and usability of GEWEX products with ANDEX researchers. From there, the global, general framework can be refined over time from the design, implementation, and evaluation of these processes, mechanisms, and approaches. The plan is for these local studies to eventually inform the development of a general framework used to orient future GEWEX activities, meeting the demand to propagate findings from one region to another and synthesize results about effective coproduction at a general or abstract level.

Possible science questions to focus on for this effort include:

1. What are the boundary objects that have successfully been implemented in RHPs? What features of these successful projects appear to have global relevance?
2. What are the main features of the context in which coproduction will happen that are drivers or barriers to process success?
3. What are the main features of the context of use that influence the uptake and active use of information?
4. What are the identifiable drivers and challenges for coproduction in the region of interest, and how do these impact the generation of actionable products?
5. What mechanisms are most fruitful for codesigning metrics to assess both the adequacy and relevance of climate information for actionable purposes?
6. What are the best practices for promoting interactions between producers and users of climate information to ensure credibility, salience, and legitimacy?
7. What are best practices for bringing awareness to, and managing, the role of values in coproduction?
8. What are the best options for codesigning research problems and methods for construction of solutions given the context of GEWEX projects?
9. What are the institutional factors of GEWEX RHPs, and more broadly GEWEX and WCRP, that are enablers or barriers to coproduction of actionable research products?
10. How can we adapt existing research methods and frameworks to better respond to the contextual features that influence the uptake and use of information products?

The immediate need is to determine the interest of the community and partner with GHP leadership to create a team for this effort. If you have interest, would like to know more, or would like to collaborate and contribute, please email Monica Morrison at *monicamo@ucar.edu* and copy *gewex@gewex.org*.

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Meeting/Workshop Reports

1st LIAISE Conference and Determining Evapotranspiration (dET) CrossCut Workshop

Lleida, Spain
27–29, March 2023

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Workshop Objectives

The overall objective of the Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) project is to improve our understanding of the impact of anthropization on the water cycle in terms of land-atmosphere-hydrology interactions, and the limitations of models to represent all aspects of the terrestrial water cycle in a semi-arid environment characterized by strong surface heterogeneity owing to contrasts between the natural landscape and intensive agriculture (*https://www.hymex.fr/liaise/index.html*). The LIAISE study area is located over the Catalan counties of Urgell and Pla d'Urgell within the Ebro basin in northeastern Spain, which contains a sharp delineation between a vast, nearly continuous intensively-irrigated region and the dryer natural zone to the east. The main water source consists of artificial reservoirs located to the north in the Pyrenees mountains, and this water is brought into the irrigated area using a highly anthropized river and canal network. The ability to make robust estimates of water use efficiency (WUE) is critical for managing the limited water resources in this region. Evapotranspiration (ET) is the process linking the water, energy, and carbon cycles, and modulating the WUE. ET is a challenge to observe and model across a range of spatial scales using a myriad of methods (Cuxart and Boone, 2020): it was studied extensively during the LIAISE field campaign in 2021 from very different perspectives, ranging from a focus on process understanding and prediction by Earth system modelers, to quantification at a range of spatio-temporal scales for hydrological or agricultural applications, such as reservoir dam regulation or crop irrigation.

The LIAISE field campaign was the first of the GEWEX determining EvapoTranspiration (dET) cross-cut initiative, which focuses on measuring ET, especially in terms of the surface energy balance, ET-atmospheric boundary layer (ABL) interactions, modeling and parameterizations of ET (notably within numerical models), partitioning of ET into its various components (bare soil, transpiration, etc.), and the quantification and study of potentially-significant spatial heterogeneity of ET. The goal of the joint LIAISE-dET meeting was to bring together researchers specializing in estimating ET experimentally using in-situ observations, via remote sensing data and/or models, from the leaf to the regional scale.

Conference Summary

The workshop was held near the end of March at the Parc Científic i Tecnològic Agroalimentari de Lleida, in Lleida, Spain (*https://www.gewexevents.org/meetings/liaise-and-det/*). There were 41 oral and 15 poster presentations, and over 60 participants attended the 2.5 day event. It brought together experts from diverse disciplines who study ET, consisting mainly of agronomers, hydrologists, meteorologists, soil scientists, remote sensing specialists, and plant physiologists, with a majority presenting results from LIAISE field campaign data analysis and numerical modeling experiments (see Boone et al., 2021 for a review of the field campaign). It was the first opportunity for many of the researchers present to finally meet face-to-face in the same location, since contact between groups was limited during the campaign due to the COVID-19 sanitary crisis.

Sessions were organized around three topics: (i) land surface ABL conditions during the LIAISE campaign, with a focus on the contrasting conditions over the irrigated and rain-fed areas; (ii) ET derived from observations using both in situ measurements and remote sensing techniques over a range of spatial scales (from plot to region); and (iii) integrated land-atmosphere-hydrology interaction studies. Note that the ET studies were not limited to the LIAISE study area. All of the presentations and posters are available on the LIAISE project page (*https://www.hymex.fr/liaise/LIAISE_conf/Workshop_March_2023/presentations/*).

After the end of the conference at mid-day on the 29th, the afternoon was devoted to LIAISE working group (WG) meetings. These groups form the core of the LIAISE project, and tie in with the dET initiative. There are three WGs, and their name and focus are defined as follows: *Surface processes* (WG1) focuses on water, energy, and carbon balances and related processes in the interaction between the surface and the atmosphere (with ET as a key process that integrates all three balances) from the leaf to the field scale. *Meteorology* (WG2) deals with ABL processes and mesoscale circulations related to wet-dry surface contrasts, topography, and sea breeze interactions. Fire, as a fundamental feature of semi-arid landscapes with strong surface-ABL interactions, is also included. *Regional scale hydrology* (WG3) explores the linkages between irrigation, streamflow and reservoirs (and their regulation), and regional-scale estimates of surface properties related to soil moisture.

Each WG meeting took place in a parallel session, with the final plenary session devoted to short presentations by each of

Attendees of the 1st LIAISE Conference and Determining Evapotranspiration (dET) CrossCut Workshop

the group leads and discussions. The main outcomes are as follows: WG1 discussed the first results of the ET-methods (eddy-covariance, gradient, lysimeter, scintillometer, remote sensing algorithms) intercomparison effort, how to best organize the various LIAISE data products for general use, the new LIAISE Unified Eddy Covariance flux product, the ecophysiological measurements (leaf area index, vegetation cover fraction, photosynthesis traits), soil moisture, and the development of consistent locally-informed land use and irrigation maps (such maps are generally superior in quality to the default global data sets often used by land surface modelers). WG2 reviewed the progress of the LIAISE mesoscale model intercomparison project (the current pilot study and a future follow-up, which will focus on an Intensive Observation Period from the LIAISE campaign); the atmospheric observational data, which has been processed and is available (e.g., ultra high frequency wind profiler, radio soundings), and the current status of data processing (e.g., turbulence from aircraft and tethered balloon); mesoscale circulations within the LIAISE region (wet-dry surface induced, the sea breeze, nocturnal jets and mountain-induced circulations); plans for large eddy simulations (LES) over the LIAISE domain by several groups; a specific study on two rain events during the special observation period (the focus thus far has been on clear days); and synergies with other projects exploring the impact of land surface heterogeneities on the ABL and subsequent mesoscale circulations [e.g., Model and Observation for Surface-Atmosphere Interactions, MOSAI, https://en.aeris-data.fr/projects/mosai-2/, or the GEWEX-sponsored Coupling Land and Atmosphere Sub-grid Parameterizations (CLASP) project (Chaney et al., 2023)]. WG3 focused on whether current land surface and hydrological models can simulate a realistic water cycle at km-scale resolutions in mountainous areas. This is especially important in a semi-arid region like the Ebro basin, which has limited water resources and where mountain reservoirs provide drinking water to the local population, generate a substantial amount of electricity, and feed the canals that provide irrigation water for intensive agricultural activities. The main scientific objectives for a regional-scale model intercomparison project (MIP) were discussed. First, adequate (high) spatial resolution input atmospheric forcings are key. Bias correction methods were presented that combine observations gathered in the Système d'analyse fournissant des renseignements atmosphériques à la neige (SAFRAN) reanalysis system (Quintana-Seguí et al., 2016) and simulated values from a km-scale model run executed within the European Climate Prediction (EUCP) system project (https://cordis.europa.eu/project/id/776613). The aim is to combine the available observations in low-lying areas with the simulation of near surface conditions over high elevation areas. An analysis of this new data set showed that precipitation is enhanced over high elevation areas as expected, while the evaporative demand, on the other hand, is reduced over these areas. These presentations led to a discussion of the potential coordinated land surface and hydrological MIP that could be proposed to the community. All three groups then met together and summary conclusions were made, mostly related to future WG activities in the upcoming few years (notably for the aforementioned intercomparison projects).

Public Outreach

Drought is predicted to be one of the main effects resulting from climate change in the Mediterranean. The frequency and severity of meteorological and hydrological droughts have increased in the recent past, and it is expected that this trend will continue in the 21st century in the Mediterranean, resulting in a major competition for water resources between different domestic, agricultural, industrial and tourism uses. Taking advantage of the LIAISE conference and the beginning of an uncertain irrigation campaign (owing to historically low reservoirs this year in the LIAISE region), a public outreach day entitled *Climate change, drought, meteorology and its impact on water resources in Mediterranean agriculture: the LIAISE project* was organized with the aim to present highlights from the LIAISE conference to the main irrigation actors (water managers, farmers, and local politicians) at the Espai Cultural dels Canals d'Urgell (Urgell Canal Cultural Space) in Mollerussa, Spain, located within the heart of the LIAISE field campaign domain. In addition, this meeting provided a forum for debates with experts on how weather prediction models can be improved, how the drought can affect such irrigated areas of the Mediterranean, and potential strategies for how water resources can be managed best. The meeting was organized by the Institute of Agrifood Research and Technology (IRTA), The Catalonian Meteorological Service, and the Irrigation Authority in collaboration with the LIAISE project steering committee.

Next Steps

The LIAISE database is being updated continuously with processed field campaign data along with products derived using models and data from local sources, such as regional land cover and soil property maps. The data catalog can be viewed at *https://liaise.aeris-data.fr/*. Note that there is an embargo in place that restricts the data to those who have requested and been granted access; in less than two years, the data will be available via open access. This data is central to the WG activities, and these groups will continue to function through at least the next two years. Several data product and model intercomparison projects are either already underway (e.g., ET products, the mesoscale MIP) or will begin (regional hydrological MIP) within the next year or so, and they are being run through the WGs. Those interested in following or joining a WG are invited to visit the LIAISE WG webpage for more information. Some of the instrumented sites have remained or will be renewed within the LIAISE region: the Mollerussa potential evaporation site has been taking measurements since the campaign was conducted in 2021 along with the weighing lysimeters; the Els Plans rain-fed super-site 50m tower and several remote sensing instruments remained operational for approximately a year after the campaign; a surface energy balance (SEB) station and lysimeter are currently present and will be operational until at least autumn 2025; and an eddy covariance site will be installed along the shore of Lake Ivars by the end of this year, owing to the interest the campaign data generated for the lake managers. The public outreach was deemed a success, and allowed a lively debate between the scientists involved in LIAISE and local stakeholder and decision makers. As the extreme drought conditions experienced this spring in the region have already resulted in significant crop losses for many of the regional farmers, it was a timely event. LIAISE will continue to remain active in exchanges with the local water management and agricultural sectors. Finally, a future workshop will be planned, likely either in conjunction with or adjacent to the 10th International Conference on Meteorology and Climatology of the Mediterranean (MetMed) meeting, tentatively planned to be held in Toulouse, France, in spring 2025.

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The Joint Ninth Aerosol, Clouds, Precipitation and Climate (ACPC) initiative and TRacking Aerosol Convection interactions ExpeRiment (TRACER) Workshop

Houston, TX, USA and Online
16–19 May 2023

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The joint ninth Aerosols-Clouds-Precipitation-and-Climate (ACPC; *http://www.acpcinitiative.org*) initiative and TRacking Aerosol Convection interactions ExpeRiment (TRACER; Jensen et al., 2022) workshop was convened from 16–19 May 2023 at Texas Southern University (TSU), Houston, TX, and online to discuss progress towards understanding the interactions among aerosols, clouds, precipitation, and climate. The event was organized around the two ACPC working groups, one focusing on aerosol interactions with deep convective clouds (Jensen et al., 2021) and the other focusing on aerosol effects on low clouds, particularly through the study of "natural laboratories" (Christensen et al., 2022). During these sessions, participants discussed progress aligned with the ACPC roadmaps and updates on related research activities. Researchers from around the globe presented their work, using a hierarchy of modeling and observational approaches.

The first day of the meeting was devoted to reports on the data collected during the TRACER campaign, initial analyses, and research plans, with the second day focused on other ongoing ACPC deep convection research activities and discussions of next steps along the ACPC deep clouds roadmap (Jensen et al., 2022). Ongoing ACPC research activities were presented that focused on disentangling the influences of aerosol, cloud microphysics, and meteorology on convective lifecycle. The relative importance of these processes and their impacts was reported to depend strongly on the character of the convective cloud and its forcing mechanism. The important role of model grid resolution on the representation of convective scale processes was quantified and highlighted as a remaining challenge for convective simulations. Even within these obstacles the significance of the representation of cloud condensation nuclei profiles in the modeling of different characteristics of severe weather was demonstrated. The importance of convective vertical transport for the profile of new particles in the atmosphere produced during both weather events and wildfires was presented. The impacts of these particles on convective clouds were found to depend strongly on the particle size (ul-

trafine vs. accumulation mode aerosols) and lifecycle stage of the convection. Supersaturation in clean updrafts determines the potential of convective invigoration by aerosols through condensation, and there was interesting discussion concerning how high supersaturation can be and how it depends on droplet number concentrations and updraft speeds.

A major focus of the discussion was the planned TRACER model intercomparison project (MIP), which follows on from the first ACPC MIP (Marinesco et al., 2021). The TRACER MIP will have a focus on examining the factors and processes that lead to model biases and spread in the simulation of aerosol-convection interactions for cases from the TRACER campaign, taking advantage of comprehensive observations collected. Some improvements over the first ACPC MIP will be: (1) extensive model evaluation against observations from TRACER; (2) at least two cases with different dynamic, thermodynamic, and aerosol conditions; and (3) explicit consideration of ultrafine aerosol sizes using both prescribed and prognostic aerosols. One of the specific challenges that was discussed during the meeting was how to account for the significant heterogeneity of the air mass and surface characteristics experienced by convective cells through their lifecycle. The ACPC TRACER MIP invites participants to join the effort, which includes models of varying complexity.

In-person attendees at the 2023 ACPC/TRACER meeting. Photo credit: Andrew McCray

A day and a half were devoted to presentations and discussions on shallow clouds. The presentations covered a mix of observations and modeling at different scales, ranging from large eddy simulations to global effects. Several recurring themes emerged from the discussions. Cross-scale modeling work and comparisons to observations in specific regions, particularly the NE Atlantic around the Azores Atmospheric Radiation Measurement (ARM) site and the SE Atlantic region, which have been the sites of recent field projects, were highlighted. A new focus in recent years has been on examining the time-dependent evolution of clouds using both Eulerian and Lagrangian methods. Novel techniques, such as wavelet analysis and cloud tracking within regional-scale models, were demonstrated to provide additional constraints for quantifying the impact of aerosols on cloud evolution. Ongoing research is being conducted on natural laboratories for aerosol perturbations, including volcanoes, industrial point sources, ships, and events such as the COVID pandemic. Industrial sources and mixed-phase clouds, as well as regions with "ship tracks", were also discussed. There is a desire to develop coordinated cross-scale modeling experiments and compare observations and models ranging from large eddy simulations to global scales in the same regions. Ship emissions and ship tracks were another topic of several presentations, including the analysis of satellite and in situ observations, as well as some modeling studies. Several new studies focused on the International Maritime Organization's 2020 (IMO2020) sulfur regulations, indicating a significant reduction in visible ship tracks. Efforts are underway to compare and summarize the existing knowledge. Finally, several presentations discussed or alluded to applications related to Marine Cloud Brightening, which serves as a motivation for studying the effects of cloud aerosols over the ocean.

Based on the outcomes of this meeting, several coordinated ACPC shallow clouds projects are being launched. A synthesis of the IMO2020 shipping regulations is currently underway, and a group is exploring ideas for a coordinated cross-scale modeling and observational analysis of specific natural laboratories to enhance our understanding of shallow cloud and aerosol interactions.

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Report on the Climate Change, Water Resources and Agriculture in Central Asia Workshop

Tashkent, Uzbekistan
May 18–20 2023

Michael Brody[1] and Peter van Oevelen[2]

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The GEWEX workshop, *Climate Change, Water Resources and Agriculture in Central Asia* (*https://www.gewexevents.org/meetings/water-resources-central-asia/*), was recently held from May 18–20 2023 at the National Research University Tashkent Institute of Irrigation and Agricultural Mechanization Engineers of Uzbekistan (NRU TIIAME). The main goal of the workshop was to facilitate collaborative discussions for study led by Central Asian researchers. This core group would then work to establish a regional project in Central Asia on hydroclimate, water resources, food security, conservation, and land use. A crucial aspect for successful regional project development is the existence of a strong and cohesive scientific and stakeholder network, an established community with relevant interests. Such a community can better observe and predict climate change and its effects. This will support adaptation and mitigation measures for improved water resource management, land use planning, and food supply sustainability.

The workshop was organized through a collaboration between GEWEX/George Mason University (USA), Wageningen Metropolitan Food Clusters/Wageningen University and Research (The Netherlands), the Central Asia and South Caucasus consortium of Agricultural universities for Development (CASCADE), the EcoGIS center of TIIAME (Uzbekistan), and the Research Institute of Environment and Nature Conservation Technologies at the Ministry of Nature Resources of the Republic of Uzbekistan (Uzbekistan).

In addition to the organizing committee, the small group of very active participants came from TIIAME; the American University of Central Asia in Bishkek, Kyrgyzstan; the University of Central Asia, in Bishkek; the Kazakh National Agrarian Research University in Almaty, Kazakhstan; and the Tajik Agrarian University in Dushanbe, Tajikistan. Additional participants were from the TIIAME Qarshi Institute of Irrigation and Agrotechnology, the Northwest Agriculture and Forestry University of China, the Turin Polytechnic University in Tashkent, and the International Center for Agricultural Research in the Dry Areas (ICARDA). A foundation for this workshop was the 2021 GEWEX, American University of Central Asia (AUCA), and SysTem for Analysis, Research and Training (START) online workshop (find the workshop report at *https://www.gewexevents.org/wp-content/uploads/Workshop-on-Central-Asia-Report.pdf*).

The opening address was given by TIIAME's Vice Rector, Abdulhakim Salokhiddinov, in which he emphasized that Central Asian countries face severe challenges due to ongoing climate change, particularly related to water resource management and all related issues of agriculture, which require joint efforts among the countries. Developing sustainable solutions for land use and water-related challenges is the urgent task for this region to become climate-resilient.

Specific objectives of the workshop included:

- Identifying strengths and gaps in climate-related agricultural research
- Developing a vision on mid- to long-term future scales (2050) on integrated water management and food security
- Beginning to build a regional network that includes early career researchers and students and identifies their current priorities for study
- Convening climate, agricultural, and hydrological researchers to share ongoing climate-related problems and actions
- Sharing knowledge about remote sensing approaches to complement on-the-ground measurements of climate-related stresses to agriculture
- Identifying what is being measured and what is not being measured, particularly in the areas of soil and water stresses from increasing temperatures and changes in precipitation and their consequences for land use, food security, and biodiversity
- Identifying connections with regional level climate projects

Summary of the Presentations

There were 12 time-limited presentations, and some important views gathered from the talks are summarized here.

The first technical presentation was a broad overview (P. van Oevelen) of the GEWEX science needs, which include:

- Assessments of data sets related to (global) water and energy fluxes and their consistency (difficult to fund, but essential), along with their uncertainty and error characterization
- Support of in situ observational networks in the long-term, which are especially needed in Central Asia, complemented by mutually supportive modeling and process studies

Alim Pulatov, director of the EcoGIS Center at TIIAME, gave an overview of cooperation among Uzbek universities on Earth observation and remote sensing studies. These studies are generally designed to support land management, including classification of farm fields, assessment of soil salinity, and landslide susceptibility assessment. Major areas of research also include evapotranspiration assessment, precision agriculture, smart water management, and finally, forest resources assessment in Uzbekistan.

Several studies from Tajikistan (H. Safarov and M. Mirzoev) applied remote sensing, GIS technologies, and permanently-operating satellite base stations for monitoring land and water. Applications were developed to identify emerging issues such

Participants at the Climate Change, Water Resources and Agriculture in Central Asia Workshop in Tashkent, Uzbekistan

as gully formation, pasture exposure and overuse, erosion, land degradation, salinization, and landslides. Generally, observations will be used to detect the deterioration of the state of land from climate change on the production of agricultural goods over the last 20 years.

This will include identification of changes in the state of ecosystems during the last 20 years, and the impact of climate change and variability on agricultural production and the environment. An integrated monitoring network for changes in riverbed processes will be developed for an assessment of the degree of stability of river valleys under extreme climate change conditions. This will enable creation of a database on climate variability and river channel modification that will help our understanding of the potential problems of newly-irrigated territories and approaches to reclamation of agricultural lands.

The Mountain Societies Research Institute (MSRI; M. Kulikov) of the University of Central Asia (located both in Tajikistan and Kyrgyzstan) studies complex Earth surface and environmental processes and interactions that affect mountain societies. Their research is interdisciplinary and is designed to improve mountain livelihoods through sustainable management of natural resources, mitigating the effects of natural hazards and climate change and building community resilience. Several specific research areas include: innovation in snow avalanche monitoring in the remote high mountains of Central Asia, impacts of climate change on food security and health, high-resolution forest mapping, and agrarian change and labor migration in rural Kyrgyzstan.

A group of researchers at AUCA (S. Orunbaev) in Bishkek focuses on studying the development of river systems, water reservoirs, ecosystems, and risks, as well as the impact of climate change on water resources, reflecting the importance of understanding and managing water-related challenges in the region. A presentation on the role of soil water and heat transfer in ecosystem function (L. Yu, Northwest China A&F University) looked at the physics in the early thawing of frozen soils. Vegetation greens earlier in response to the early warming of subsurface soil, which affects the cold region ecosystem functioning and carbon status. E. Weitsma (Wageningen Metropolitan Food Clusters) discussed modernizing food production from all economic, social, and environmental perspectives of sustainable development. An extremely relevant discussion to Central Asia was held on governmental strategies for food security and safety, and development the agro-food system as a pillar of the national economy.

Finally, a presentation by M. Kussainova of the Kazakh National Agricultural Research University examined the effects of excessive water use and agriculture intensification on the ongoing decline of the Aral Sea, including looking at the socio-economic systems within the Syr Darya river basin. This included studies of the interdependent changes of food, energy, and water fluxes to develop mechanistic understandings of coupled changes between climate and land use. Additionally, critical drivers (including policy) were identified for stream flows and evapotranspiration loss for the sustainable future of food, water, and energy. Emissions of greenhouse gasses from fertilizers and tillage types were analyzed. Open-access websites and use of digital technologies to share all data and research findings are also a critical part of these projects.

Discussions after the presentations provide a basis for future collaborations. Major conclusions include:

- Meteorologic stations and data need to be regional and governments need to share these data
- Since the region has significant trans-boundary rivers, stream monitoring needs to be regional, rather than country-based; thus, monitoring data and trends should be analyzed regionally
- The amount of water used in agriculture needs to be better quantified along with its effects on regional hydrologic systems
- Hydromet stations across the region should transect elevation, not just in glaciers, but also at lower elevations, and there should be standardized data collection procedures across the regions
- Biomass and carbon stock assessments are needed for carbon fluxes
- Models are needed to help understand which parameters are most important for understanding the future of regional climate and water systems and for the design of observational networks.

All the presentations are available at: *https://www.gewexevents.org/meetings/water-resources-central-asia/agenda/*. For more information, contact Michael Brody at *mbrody4@gmu.edu* or Peter van Oevelen at *pvanoevelen@gewex.org*.

Report of the ANDEX 2023 Meeting

Santiago, Chile
May 3–5, 2023

Jhan-Carlo Espinoza[1], Eleonora González Porcel[2], and Mariano Masiokas[3]

[1]Institut des Géosciences de l'Environnement (IGE), IRD, UGA, CNRS, France; Universidad Católica del Perú (PUCP); [2]Centro de Estudios en Relaciones Internacionales y Medio Ambiente (CERIMA), Mendoza, Argentina; [3]Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales (IANIGLA-CONICET), Mendoza, Argentina

The annual meeting of the Regional Hydroclimatic Program for the Andes (ANDEX, *https://www.gewex.org/gewex-content/uploads/2023/04/ANDEXDossier_English.pdf*) was held in Santiago de Chile between May 3 and 5, 2023. The activities took place at the Beauchef headquarters of the Faculty of Physical and Mathematical Sciences of the Universidad de Chile. The event opened with a High Level Meeting (HLM) on the morning of May 3rd. The gathering was attended by representatives from different agencies, programs, and research projects that showed their interest in collaborating and coordinating actions in the Andean region through a close partnership with ANDEX. The World Climate Research Programme (WRCP), GEWEX, the Instituto Nacional de Investigación en Glaciares y Ecosistemas de Montaña (INAIGEM, Peru), the Servicio Meteorológico Nacional of Argentina (SMN), the Inter-American Institute for Global Change Research (IAI), and the Agence Française de Développement (AFD) participated with institutional and scientific presentations. In addition, the International Network for Alpine Research Catchment Hydrology program (INARCH), the ANDES Climat-Cryosphère-Hydrosphere project (ANDES C2H-IRD), the Mountain Research Initiative (MRI), Climate and Cryosphere Project (CliC), the National Aeronautics and Space Administration (NASA), and the South America Affinity Group (SAAG) shared their proposals and linkage opportunities.

Some participants of the ANDEX 2023 Meeting

In the afternoon of May 3rd, and during the following two days, 45 ANDEX researchers participated in intensive reflection and work sessions. Scientists based in Colombia, Peru, Bolivia, Chile, Argentina, Uruguay, the United States, France, and Switzerland attended in person and remotely. The discussions started with an updated description of the actions made since the last ANDEX meeting in September 2022, including the new structure of the program and the series of webinars that have been organized to share the advances and challenges of the study of the hydroclimate of the Andes as a bridge between scientific developments and public policies. Other activities mentioned at the meeting include ListANDEX (*https://groups.google.com/g/listandex*), a new dissemination and discussion group for hydroclimate-related issues in the Andes, and JovenANDEX (*https://docs.google.com/forms/d/e/1FAIpQLSfMUSU1rR191qHL2K7RFaqRl7ou6VxuiV5YGogpKHXHENKfAg/viewform*), a network of young researchers working on Andean hydroclimatology and related issues. Subsequently, the team of specialists worked on the identification and design of the key projects that will be part of the ANDEX Scientific Plan, aligned with the two main research themes of the program: water security for Andean populations, and reduction of risks associated with high-impact hydroclimatic events.

ANDEX is especially grateful to the Universidad de Chile and the Center for Climate Science and Resilience (CR², Chile) for hosting the annual meeting of the program. It also thanks GEWEX/WCRP for the permanent support, and the Institut de Recherche pour le Développement (IRD, France), the Pontificia Universidad Católica del Perú (PUCP, Peru), and the Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales (IANIGLA, Argentina) for their collaboration.

About ANDEX

ANDEX is an interdisciplinary scientific network organized into disciplinary teams, cross-cutting lines, and integrative services, with the overall goal of improving the understanding and prediction of the climate and hydrology of the Andes mountains. It reports to the Hydroclimatology Panel of GEWEX, which is one of the core projects of WCRP. ANDEX was created in 2018, and in March 2022, it was accepted by GEWEX/WCRP as an initiating Regional Hydroclimate Program (RHP). Currently, the team is elaborating on the scientific plan of the program for the next 10 years. The overall goal of this plan is to strengthen the resilience of Andean societies through the production and dissemination of knowledge and information on regional hydroclimate and the impacts of environmental changes on Andean populations and ecosystems. If you are interested in participating in or contacting ANDEX, please reach out to us at *contact.andex@gmail.com*.

Global Water Futures (GWF) Holds Its Final Annual Open Science Meeting, Announces an Extension to 2025 and Launches the Global Water Futures Observatories Project

Saskatoon, Saskatchewan, Canada
May 15–17, 2023
https://gwf.usask.ca/gwf2023

John Pomeroy, Corinne Schuster-Wallace, and Chris DeBeer
Global Institute for Water Security, University of Saskatchewan, Saskatoon, Canada

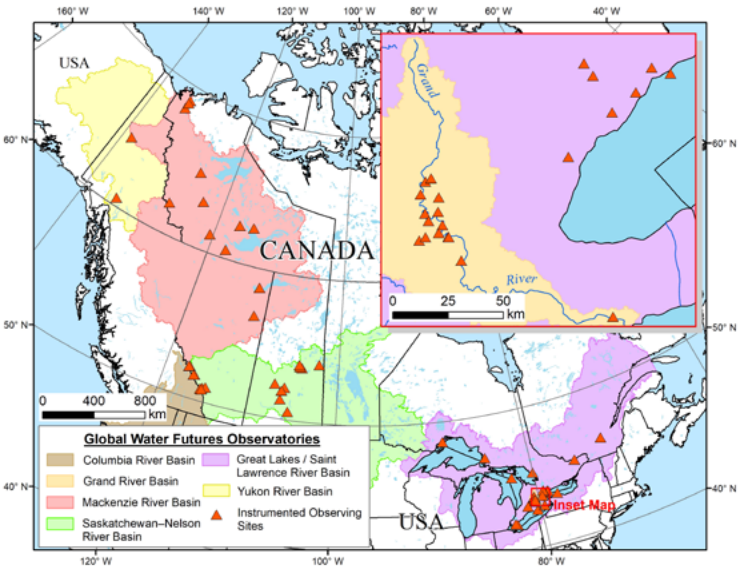
The Global Water Futures Research Program and the Canadian Regional Hydroclimate Project

Global Water Futures is a nine-year research program led by the University of Saskatchewan (USask), Wilfrid Laurier University, the University of Waterloo, and McMaster University. Its mission is to 1) Improve capability for water-related disaster warning, 2) diagnose and predict water futures and future impacts on society and ecosystems, and 3) develop new models, tools, and approaches for managing water-related risks, including adaptation to change and risk management. GWF includes 23 Canadian universities, 213 faculty investigators, and 531 partner organizations that have co-developed 65 projects and core teams that have trained and employed over 1,800 students, scientists, engineers, and technicians. GWF science focuses on diagnosing and predicting change in cold regions, developing big data and decision support systems, and designing user solutions. In support of this, it develops, couples, visualizes, and applies sophisticated atmospheric, hydrological, water resource, and water quality models and operates dozens of highly instrumented field research sites and water laboratories. In 2018, the GWF Canadian Regional Hydroclimate Project (RHP) of eight major river basins from coast to coast to coast, including boundary waters with the United States, was adopted by GEWEX. This RHP addresses distinctive cold regions and transboundary aspects that are of unique interest to GEWEX, in particular the GEWEX Science Goals for Prediction, Inter-relationships, and Human Influence, and the World Climate Research Programme (WCRP) Grand Challenge on Water for Food Baskets of the World.

The GWF program began in 2016 and has been extended for two years to 2025. Its management structure, water observatories, laboratories, and data management system will continue to operate as the Global Water Futures Observatories (GWFO) to at least 2029 and will inform and support several follow-on modelling and science programs that will coordinate with GWFO.

GWF Open Science Meeting, Saskatoon, May 15–17, 2023

GWF held its final open science meeting in Saskatoon in May at TCU Place and Wanuskewin Heritage Park. This brought together 256 people in person and 78 people online, including GWF researchers, students, post-doctoral fellows, Indigenous community partners, practitioners, water managers, watershed stewards, politicians, and engaged members of the public. This meeting provided opportunities to present the major outcomes of GWF and begin the effort of synthesizing them into a user question-centric framework. The meeting was all in plenary and consisted of panel discussions and presentations on the major thematic and topical aspects covered by GWF. Participants shared activities, results, impacts, and stories, and there were 109 science posters presented. There was a public art exhibition featuring artwork from the Virtual Water Gallery, which remained up throughout the meeting, and the Young Professionals organized a social event and a tour of the USask Centre for Hydrology's Smart Water Systems Laboratory. A major highlight was a gathering that took place at Wanuskewin on May 15 where Indigenous partners shared perspectives and experiences and presented the GWF Mistawasis Nêhiyawak Statement–Everyone Together. This is an outcome of the Indigenous Water Gathering that took place at Mistawasis Nêhiyawak First Nation in Saskatchewan in April 2023. Plenary speeches were given by the Vice President of the Saskatchewan Water Security Agency and the federal Parliamentary Secretary to the Minister of Environment and Climate Change. More details on the GWF Finale, including a recording of the meeting and other materials, are available at https://gwf.usask.ca/gwf2023/index.php.



A map of the GWFO instrumented sites, showing the program's geographical scope moving forward

Meeting Statements and Conclusions

GWF researchers, partners, collaborators, and information users met in Saskatoon during yet another period of record heat and exceptional wildfires and floods to reconnect and share information on the state of our knowledge as the program nears its completion.

Global Water Futures has amassed a vast amount of knowledge through research and working with many partners and collaborators, including Indigenous partners, across knowledge systems and within the uncertainty of our water futures in Canada.

Over the past seven years of the program, we have completed laboratory, theoretical, fieldwork, and community research activities as well as modelling, visualization, sensor, and tool development.

We have increased knowledge on the changing climate and weather extremes; changing water budgets, lakes, wetlands, groundwater, and rivers; Indigenous community water issues; and changing agriculture and forested basins, including human dimensions and water management solutions in Canada and around the world. We have developed new sensors, satellites, data management, and water prediction models that are world-leading and being applied globally.

We continue to complete and distribute the findings of our research through workshops, sectoral meetings, stories, art, music, model applications, and publications of papers and data.

We now launch the GWF Synthesis in collaboration with our partners while continuing our communication and outreach through regional and sectoral science discussions and custom knowledge translation applications.

Moving Forward–Global Water Futures Observatories (GWFO)

The Canada Foundation for Innovation (CFI)'s Major Science Initiative (MSI) Fund has provided partial funding to 2029 (renewable thereafter) for a subset of GWF called the Global Water Futures Observatories project (GWFO). This will support GWF's management of data, observations and science, some of its outreach and knowledge mobilization with data users, and the operations of 64 instrumented basins, lakes, rivers, and wetlands, 15 deployable observation systems, and 18 state-of-the-art water laboratories that provide urgently-needed scientific data to deliver flood, drought, and water quality solutions. This MSI project sustains the legacy of GWF's unique freshwater observing network and sophisticated data telemetry, storage, management, and visualization system as the GWFO facility. This will keep observational and data aspects of GWF going, will coordinate with science and modelling projects that can leverage the observational data, and will continue to contribute to GEWEX.

GWFO Vision: To operate a national water observatory consisting of a network of instrumented water observing sites, supported by deployable observing systems and major laboratories, that provides open access water data and the necessary infrastructure to collect supplementary data, which informs the development and testing of water prediction models, monitors changes in water sources, underpins diagnosis of risks to water security, and helps design solutions to ensure the long-term sustainability of Canadian water resources.

Principles of Operation/Inclusion for Observation Sites and Laboratories:

- Provide unique water data of interest to characterizing and monitoring the water conditions of Canadian river basins
- Contribute to a critical baseline of water data to the benefit of multiple users
- Support the data collection from, and analysis of, water from the network of instrumented water observing sites
- Adhere to the principles of open access

2023 GEWEX Hydroclimatology Panel (GHP) Meeting

Maynooth, Ireland
5–7 July 2023

Ali Nazemi[1], Paola Arias[1], and Francina Dominguez[2]
GHP Co-Chairs; [2]Past GHP Co-Chair

Following the return of the in-person GHP Panel meeting in Monterey, California in 2022, the 2023 meeting was hosted by Maynooth University in Ireland's only university town. Benefitting from warm and generous Irish hospitality, the meeting provided an opportunity for lively peer-to-peer interactions during morning and afternoon sessions. Although most of the Panel members and project leads attended the meeting in-person, some attendees participated virtually and actively engaged in the discussions. Some procedures set during pandemic, e.g., submission of documents prior to the meeting and allocating most of the meeting time to discussions, are now established as regular routines and have boosted the effectiveness of the GHP meetings quite significantly.

GHP comprises four different types of projects: (1) Regional Hydroclimate Projects (RHPs), aiming at understanding and predicting hydroclimatology in a specific region; (2) Crosscutting Projects (CCs), encouraging knowledge mobilization and global synthesis of knowledge around a specific topic; (3) Networks, maintaining collaboration and building capacity for activities relevant to GEWEX science; and (4) Global Data Centers, collecting and distributing hydrologically-relevant data. During the GHP meeting, the group reviewed and discussed the progress of ongoing and prospective projects in these four categories. The Panel also discussed some internal matters, welcomed a new member and Co-Chair, and celebrated the dedicated service of the past Co-Chair and two of the project leads.

Ongoing and Prospective Regional Hydroclimate Projects (RHPs)

RHPs are multidisciplinary projects to improve understanding of the physical and anthropogenic processes that affect water and energy exchanges within a large region. There are currently four ongoing RHPs in the Panel. This includes two mature RHPs, i.e., Baltic Earth and Global Water Futures (GWF), and two initiating ones, the Regional Hydrology Program for the Andes (ANDEX) and the Third Pole Environment-Water Sustainability (TPE-WS). The Panel also hosts three prospective RHPs, i.e., the United States RHP (US-RHP), the Asian Precipitation Experiment (AsiaPEX), and the Central Asia initiative.

GHP's mature RHPs include large groups of active researchers and established ties with local communities and end-users. As the Panel's oldest RHP, Baltic Earth is an example for a decentralized and bottom-up governing research program without any core funding, in which individual researchers join forces and share research interests and resources. On the other hand, GWF is an example for a centralized and top-down RHP, with a large amount of core funding. Despite their differences

in pursuing the concept of an RHP, both Baltic Earth and GWF have demonstrated solid and continuous progress and have been quite influential in the policy and decision-making spheres. Baltic Earth's assessment reports and fact sheets are now being translated to various European languages and have become a knowledge base for decision makers in the Baltic Sea region. GWF also played a critical role in the formation of the new Canada National Water Agency that will be headquartered in Winnipeg, Manitoba.

Since the beginning of 2022, ANDEX has been an initiating RHP, with over 60 researchers from seven countries in the region. They updated their Science Plan based on the Panel's response to the initial Science Plan during the ANDEX meeting in Buenos Aires, Argentina (4–6 September 2022), followed by the publication of the institutional dossier in November 2022. Considering the international attention on the first set of ANDEX review papers, the ANDEX team is now working on follow-up review articles on the state of atmospheric and hydrologic modeling in the region. ANDEX also developed a series of Spanish-speaking webinars to reach the local operational and research communities. The Panel was pleased to see ANDEX progress. TPE-WS is another initiating RHP, approved by the Panel in early 2023. The activity had a productive year by setting up new measurement sites and continuing modeling and analyses. These efforts have led to new science advances such as, e.g., understanding the significant overestimation of convective rainfall by climate models over the southeastern Tibetan plateau.

Participants, both in-person and virtual, of the 2023 GHP Meeting

We expect two prospective RHPs, the US-RHP and AsiaPEX, to receive initiating status soon. Following more than two years of hard work, the US-RHP team submitted its Science Plan prior to the meeting. The Panel recognized this as a milestone and is currently reviewing the document and preparing a formal response. After successful publication of its *Bulletin of the American Meteorological Society* (BAMS) paper, AsiaPEX is also finalizing its Science Plan, expected to be received by the Panel by the end of summer 2023. The other prospective RHP, the Central Asia initiative, needs more time to flourish. The core team recently executed an in-person workshop in Tashkent, Uzbekistan (see page 13), to facilitate collaborative discussions for research led by Central Asian researchers. This will be followed by another workshop in 2024 to form a small leadership team and to engage with funding opportunities. The Panel understands the challenges in forming a strong RHP in this region, yet fully recognizes the importance of this activity in an area that was not previously pursued by the GEWEX community.

Ongoing and Prospective Crosscutting (CC) Activities

CCs are integral activities within GHP aimed at addressing the GEWEX Science Questions and creating collaboration between RHPs, other GEWEX Panels, and World Climate Research Programme (WCRP) activities. GHP currently includes three active and four prospective CCs. The oldest CC in the Panel, the Transport and Exchange Processes in the Atmosphere over Mountains Experiment (TEAMx), aims to improve the current understanding of exchange processes in the atmosphere over mountains and how these processes are parameterized in climate models. During the reporting period, TEAMx's BAMS paper was published; the number of observational target areas increased to cover a cross-section from the northern to southern Alps; and the activity reached out to research groups outside of the Alpine region, specifically in the UK and the US, to collaborate in observational and simulation activities.

The 2nd phase of International Network for Alpine Research Catchment Hydrology (INARCH-II) is now progressing through its Common Observation Period Experiment (COPE). INARCH-II also established strong ties with RHPs and other GEWEX and WCRP activities and has become a contributor to the United Nations Educational, Scientific and Cultural Organization (UNESCO) Intergovernmental Hydrological Programme in Mountain Water Sustainability. The 2022 INARCH workshop was held in Baños de Panticosa, Spain (October 18–20, 2022), which will be followed by its 2023 meeting in Stanley, Idaho (October 9–11, 2023). The Panel is pleased with INARCH-II's progress. Determining Evapotranspiration (dET) is another active CC with the goal to advance the determination of evapotranspiration across scales. dET has now published the data related to the Land Surface Atmosphere Interactions over the Iberian Semi-Arid Environment (LIAISE) campaign. This data set can support future process understanding and simulations. The dET team also submitted its revised Science Plan, which is now being reviewed by the Panel.

GHP also includes four prospective CCs at different levels of development. The most advanced prospective CC is the Flood CC, which looks at a wide spectrum of challenges around understanding flooding processes from observations to model de-

velopment to socio-economic impact assessments. Following the survey executed in 2022, the core team will have its first online workshop in September 2023, in which experts from across the globe will discuss various aspects related to flooding in three parallel sessions. The Flood CC also proposed a session in the upcoming American Geophysical Union (AGU) Fall Meeting, which can connect the activity with the broader research community. It is quite evident that these activities will soon result in the formation of working groups and converge to defined research objectives that can be articulated in a Science Plan. In contrast, activities related to the Precipitation over Mountainous Terrains (MOUNTerrain) are in hiatus. MOUNTerrain aims at better process understanding, model development, and prediction of precipitation in mountainous terrains. The Panel considers MOUNTerrain both an important and timely activity, particularly in the context of the Global Precipitation Experiment (GPEX) project, yet it also recognizes the current challenges due to the lack of an active leadership team. The Panel discussed various options to recruit experts to take the lead and move toward a comprehensive research agenda that is distinct from, but complementary to, the activities of INARCH and TEAMx.

The meeting also included presentations that envisioned and pitched new activities, possibly in the form of new CCs. Stefan Kollet (Research Centre Juelich and University of Bonn) discussed the prospects for a GEWEX groundwater activity and the current challenges and opportunities in considering groundwater reserves and fluxes in the context of regional and global Earth system modeling. The Panel is fully supportive of this new endeavour and provided some suggestions toward better formation of this activity. Cedric David [National Aeronautics and Space Administration (NASA)'s Jet Propulsion Laboratory] also presented a vision for a global river network observational and modeling initiative, given the new opportunities rising from the emergence of the Surface Water and Ocean Topography (SWOT) data. The Panel fully recognizes the need for this initiative and can clearly see how it can complement and contribute to several GHP activities. The Panel looks forward to seeing how this activity evolves.

Ongoing and Prospective Networks

GHP Networks foster collaborations and capacity building activities relevant to GEWEX science. They may transition into an RHP upon successful initiation of research activities and sourcing of funds; or, alternatively, an RHP may transition into a Network upon completion. GHP currently hosts one active and one prospective Network. PannEx, a GHP network aiming to provide a better understanding of Earth system processes over the Pannonian Basin, is an active Network that started as an initiating RHP, and later evolved into a vibrant group of scientists from different disciplines interested in hydroclimatic processes of the region. During the reporting period, PannEx had multiple workshops and meetings and started the second edition of a special journal issue on Climatic Extremes in the Pannonian Basin.

After the official sunset of the Hydrological Cycle in Mediterranean Experiment (HyMeX) in 2020, a new group of young researchers from the region have been developing the second phase of HyMeX, initially as an RHP. Despite efforts made, the team has not yet converged toward an RHP, and it was suggested that the team organize itself as a Network, allowing for more flexibility in the research and outreach agendas. As the activity was absent in the meeting, the Panel will seek updates during the remainder of 2023.

Data Centers

GHP currently includes two Global Data Centers, the Global Precipitation Climatology Centre (GPCC) and the Global Runoff Data Centre (GRDC). GPCC is well-connected to other GHP and GEWEX activities. Steady progress was reported related to precipitation data. In parallel, GRDC focuses on acquisition, harmonization, and storage of global historical river discharge data. The center progresses very well and new data are continuously added into the system. Also, the usage of GRDC data has significantly increased since the launch of its online tool that made GRDC data accessible to the broader research community. Both GPCC and GRDC are going through leadership changes. After years of service, Udo Schneider (the ex-director of GPCC) and Ulrich Looser (the director of GRDC) are retiring and these data centers will enter a new era. GHP greatly appreciates Udo and Ulrich's years of selfless service to the GEWEX and broader research communities and is looking forward to working with new leadership teams.

Historically, the information related to surface water storage for current and future GHP activities was held by the International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE) in Russia. The Panel has commented for a number of years regarding the outdated and/or inaccessible information and the fact that HYDROLARE has been rather inactive. The Panel understands the current difficulties for Russian-based scientists to be involved in global initiatives; however, it also recognizes that a number of GHP activities need access to lake and reservoir storage and flux data. On this basis, the Panel decided to pronounce HYDROLARE dormant for the time being and approach other data opportunities, particularly through satellite remote sensing.

Other Businesses

GHP is closely linked with the GEWEX Panel on Global Land-Atmosphere System Studies (GLASS) through a number of joint activities. To facilitate the relationship between the two Panels, GHP member Joshua Roundy (Kansas University) serves as the GLASS-GHP liaison. GHP was particularly interested in knowing how activities are progressing in the Irrigation CC, an activity that is relevant to RHPs and could be linked to CCs, e.g., dET. The Panel was pleased to see that after a year of hiatus, the activities have been boosted and are taking shape; e.g., the review paper summarizing advances in irrigation models is published. However, the Panel raised a number of concerns and suggestions related to future activities of the Irrigation CC. It was decided that these issues will be discussed between the Panels' leadership.

As GHP activities are growing in number and size, discussions were made on more engagement between Panel mem-

bers and/or activities. Several suggestions were made such as having quarterly online meetings, interim reporting by activities through online presentations, and establishing a new reporting procedure, including assignment of two rapporteurs per activity during each reporting cycle. The procedure for considering new (self-)nominations was also discussed, and the Panel agreed that the assignment of new members should be based on matching GHP needs with candidates' expertise, along with consideration of regional and gender diversity. It was decided that the GHP Co-Chairs will work on integrating these ideas and will propose new operational procedures for internal Panel affairs and activities.

GHP is continuously enriched through new Panel members. This year, GHP welcomed a new member, Dr. Michael Bosilovich, a NASA Scientist based in Greenbelt, MD and an ex-GEWEX Science Steering Group (SSG) member. Dr. Bosilovich's main expertise is in climate reanalysis for quantifying the elements of water and energy cycles. Due to his long involvement with GEWEX, Dr. Bosilovich brings seniority and memory into the Panel. The Panel looks forward to benefiting from his depth and breadth of knowledge and expertise. After four years of dedicated service, Francina Dominguez stepped down as the GHP Co-Chair and Paola Arias was appointed as the new Co-Chair. The Panel greatly appreciates Francina's service and wishes all the best to Paola in the new role. *Go n-éir a bóthar leat*!

Sonia Seneviratne and Bart van den Hurk Elected to IPCC Bureau

Sonia Seneviratne and Bart van den Hurk were recently named members of the Intergovernmental Panel on Climate Change (IPCC) Bureau at the end of July. Prof. Dr. Seneviratne will be a Vice-Chair for Working Group I, and Prof. van den Hurk will serve as Working Group II Co-Chair. Prof. van den Hurk formerly chaired the Global Land-Atmosphere System Studies (GLASS) Panel and co-chairs the Land Surface, Snow and Soil Moisture Model Intercomparison Project (LS3MIP). Prof. Seneviratne was a member of both GLASS and the GEWEX Data and Assessments Panel (GDAP) and Co-Chair of the GEWEX Scientific Steering Group (SSG).

New Abbreviations and Acronyms List Now Online

The new abbreviations and acronyms list is now available at https://www.gewex.org/abbreviations-acronyms/.

GEWEX/WCRP Calendar

For the complete Calendar, see http://www.gewex.org/events/

29–31 August 2023—VII Convection-Permitting Climate Modelling Workshop—Bergen, Norway
22 September 2023—1st Global Flood Crosscutting Project Workshop—Online
25–29 September 2023—International Conference on Regional Climate (ICRC)-CORDEX 2023—Trieste, Italy
9–11 October 2023—2023 Fall INARCH Workshop—Stanley, ID, USA
16–20 October 2023—2023 Sun-Climate Symposium—Flagstaff, AZ, USA
19–20 October 2023—2023 GEWEX Data and Analysis Panel (GDAP) Meeting (*by invitation only*)—New York, NY, USA
23–27 October 2023—WCRP Open Science Conference 2023—Kigali, Rwanda
27 November–1 December 2023—Hydrospace 2023—Lisbon, Portugal
11–15 December 2023—AGU Fall Meeting—San Francisco, CA, USA, and Online
28 January–1 February 2024—104th AMS Annual Meeting—Baltimore, MD, USA
13–17 May 2024—5th Baltic Earth Conference—Jūrmala, Latvia
7–12 July 2024—9th Global Energy and Water Cycle Open Science Conference—Sapporo, Japan

GEWEX QUARTERLY

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