GEWEX QUARTERLY

WCRP

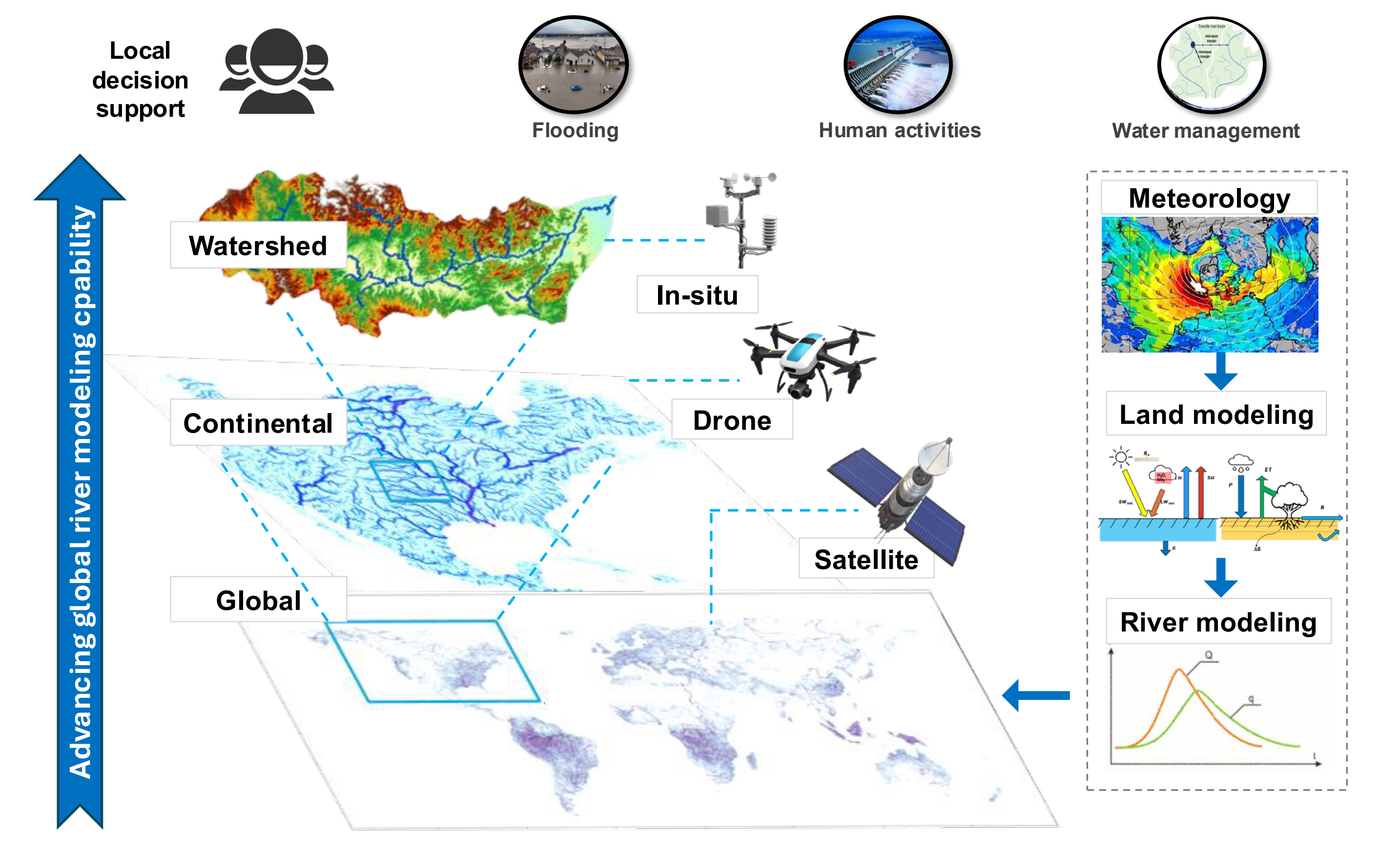
United Nations Educational, Scientific and Cultural Organization
Intergovernmental Oceanographic Commission
World Meteorological Organization
International Science Council

Vol. 35, No. 1 | Quarter 1 2025

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

A New Strategy for Comparing River Models: The RivEx Crosscutting Initiative

RivEx: Advancing Global Surface Water Science for Local Benefits



The broad objective of the River Experiment Initiative: modeling across space and time scales for the benefit of science and society. Read more about the new project in David et al., pg. 5.

Inside This Edition

Commentary & News	General Interest	General Cont'd
The value of the International GEWEX Project Office [p. 2] New SSG members [p. 3] New GASS Co-Chair, new JSC Chair and Vice-Chair [p. 3] New BSRN leadership [p. 4] Remembering Linda Mearns, former SSG member [p. 4] The 2025 GEWEX Ambassadors [p. 4]	Improving river models with RivEx [p. 5] LS4P shows that excessive TP spring warming was the primary factor in catastrophic June 2024 rainfall in Southern China and Bangladesh [p. 8] New ESA Earth Observation Science Strategy offers opportunities to advance hydrology and Earth system science [p. 11]	Study demonstrates that the TP's land conditions can provide seasonal-to-interannual predictability for extreme events [p. 12] Opportunities for water cycle research with new and future gravimetry satellite missions [p. 14]

Commentary

Jan Polcher
Co-Chair, GEWEX Scientific Steering Group

The most valuable resource for the GEWEX community is our project office (the International GEWEX Project Office, or IGPO for short). It is not only because of all the logistical arrangements it provides to the community, but also because it has a deep understanding of the diversity of the people that make up GEWEX.

IGPO is central to the communication within the GEWEX community and the rest of the WCRP world. Fernande, Shannon, and the persons before them keep the websites, online media and mailing lists up to date and circulate needed information within the community. They ensure that each GEWEX Quarterly gets assembled, corrected, and published in a timely manner and keep current the list of meetings. With the gewexevents.org site, IGPO provides a means for handling registration, document collection, and other essential services for those in the community organizing meetings. Another essential service is to identify and manage the funds needed to allow the community to meet, either in large conferences like last year in Sapporo, Japan, or more specialized meetings to hack out the last details of an experimental protocol for a model intercomparison or a field campaign.

Much less recognized is the knowledge IGPO has assembled about the community over the years. The members of the GEWEX community come from different cultural backgrounds, work in different environments, and fund their research through different processes. They can more or less easily travel to meetings because of their work environment or personal reasons. Having this very qualitative knowledge of the community is essential to ensure that meetings are the most productive for all. This involves deciding whether the issue at hand can be discussed via video conference or requires an in-person meeting to ensure the success of our initiatives. We do not all use or master the same means of communication. For most of us, English is a foreign language. This means that each one of us has a preferred way of communicating. Forcing a certain type of exchange onto a group like GEWEX can limit the results one can expect. That deep understanding of communication between scientists in the international realm has been acquired over the years through the work of Paul Try, Rick Lawford, and currently Peter van Oevelen. It is essential for the success of our community. They have ensured over the years that the right people are at key meetings and that these meetings are held in the best location to ensure the international exchanges GEWEX aims for.

This understanding of the community also allows IGPO to identify the early career researchers who would benefit most from or contribute most to an initiating activity. Or recognize when a colleague is overwhelmed by obligations at home institutions and needs to be relieved temporarily from GEWEX activities. These small and subtle decisions taken on a daily basis by IGPO keep the community together and motivated. I think all members of GEWEX know how important this service is.

The value of this knowledge of the functioning of an international scientific community has been seen in the past with other core projects of the WCRP. When the project office stopped for a few years or moved from one country to another, most of the institutional knowledge of how the community worked was largely lost. It then took years for the projects to rebuild their community and recover their efficiency in organizing research at the international level. The heritage we have with the IGPO is something that is vital for GEWEX and needs to be valued and protected.

In the current geopolitical situation, it becomes even more important to recognize IGPO's role of international coordination in the progress of our science. The more than 30 years of experience and knowledge accumulated by IGPO needs to be preserved through these turbulent times. If we wish GEWEX to continue to be the lighthouse that guides the research community working on water and energy exchanges, we need to pull together to protect our IGPO. Any ideas and suggestions to make our project office more resilient would be helpful and we would be happy to hear from you.

Table of Contents

Commentary.......... 2

News and General Interest

New GEWEX SSG Members.......... 3

New GASS Co-Chair.......... 3

New JSC Chair and Vice-Chair.......... 3

New BSRN Leadership.......... 4

In Memoriam: Dr. Linda Mearns.......... 4

Global Flood Crosscutting Initiative's Monthly Meetings... 4

2025 GEWEX Ambassadors.......... 4

The River Experiment Initiative: Advancing Global Surface Water Science for Local Societal Benefits.......... 5

Excessive Tibetan Plateau Spring Warming Found to Cause Catastrophic June 2024 Precipitation in Southern China and Bangladesh—A Typical LS4P Scenario.......... 8

Satellite Hydrology for Advancing the Coupling between Earth's Water, Energy and Carbon Cycles: An Emerging Opportunity from the Earth Observation Science Strategy of the European Space Agency.......... 11

Land's Contribution to Seasonal-to-Interannual Predictability of Extreme Events.......... 12

Satellite Gravity Missions and GEWEX: Water Cycle Applications Perspective.......... 14

Call for Papers: Two Special Issues on the GEWEX OSC.. 17

Meetings Calendar.......... 17

New GEWEX SSG Members

New GEWEX Scientific Steering Group (SSG) member Dr. Camila Alvarez-Garreton is a full-time researcher at the Center for Climate and Resilience Research (CR2) in Chile, where she leads investigative efforts on water security. She joins the SSG with a background in hydrology, modeling, and data, and a focus on physical process understanding. Her experience in interdisciplinary research coordination is complemented by participation in South American research networks such as ANDEX and network projects such as CLIMAT-AmSud. She assesses climate change impacts at multiple scales and has experience translating scientific outcomes into useful inputs for decision making.

Prof. Jason Evans of the Climate Change Research Centre (CCRC) at the University of New South Wales (UNSW) is a new GEWEX Scientific Steering Group (SSG) member. He has been involved with GEWEX for some time, having previously served as co-chair of the GEWEX Hydroclimatology Panel (GHP). His expertise is in the science of the climate system, particularly in regards to land-atmosphere interactions, the water cycle, and regional climate change. His research investigates regional climate processes, how regional climate is changing (including changes in climate extremes), and how this impacts various human and natural systems. His research involves the development and use of regional climate models to enable climate change impacts and adaptation research and applications.

Dr. Martin Best is a science fellow at the Met Office in the UK, where he leads the land surface research and development work on the energy and water cycles. He has over 30 years of experience working on all aspects of land surface modeling and was a key contributor to establishing the Joint UK Land Environment Simulator (JULES) community land surface model. After attending the GEWEX SSG-36 meeting as an invited expert, he joins the SSG as a new member with many years of experience with the GLASS Panel. He served in GLASS from 2003–2016, and as Panel co-chair for four years. He was responsible for a number of GLASS projects, including the Urban-Project for Intercomparison of Land surface Parameterization Schemes (Urban-PILPS), the PALS Land sUrface Model Benchmarking Evaluation pRoject (PLUMBER), Urban PLUMBER, and the Diurnal land-atmosphere Coupling Experiment (DICE).

Dr. Manon Sabot, Max Planck Institute for Biogeochemistry, joins the Scientific Steering Group (SSG) of GEWEX with expertise in land surface modeling and, more generally, plant-climate responses. Her research integrates field and experimental observations within both theoretical models and land-surface models to better understand soil-plant-atmosphere interactions and ecosystem functioning. She is particularly interested in extreme weather and climate events like droughts and heatwaves; under these conditions, her research also examines the eco-physiological mechanisms behind plant acclimation to climatic stress and how those mechanisms may affect model predictability, thus affecting projections of carbon, water and energy cycles globally.

New GASS Co-Chair

Dr. Shaocheng Xie of the U.S. Department of Energy (DOE)'s Lawrence Livermore National Laboratory became co-chair of the Global Atmospheric System Studies (GASS) Panel in 2025, following six years as a Panel member. His research focuses on Earth system model development, validation, atmospheric process understanding, and observational analysis. He has extensively used hierarchical modeling approaches, including Single-Column Model (SCM), Cloud-Resolving Model (CRM), Large-Eddy Simulations (LES), and short-range hindcast methods, to test cloud-related processes with field and satellite observations. As the atmospheric group leader, he led a team that developed versions 1–3 of the DOE Energy Exascale Earth System Model (E3SM) Atmospheric Model (EAM). He also led the creation of DOE Atmospheric Radiation Measurement (ARM) program's large-scale forcing data, which is widely used in GASS studies. Currently, he leads a GASS project to improve diurnal precipitation cycle simulations in weather and Earth system models.

New JSC Chair and Vice-Chair

The World Climate Research Programme (WCRP) Joint Scientific Committee (JSC) welcomes a new Chair and Vice-Chair. Professor Tim Naish of Victoria University of Wellington steps in as the JSC Chair and Professor Cristiana Stan of George Mason University is the new Vice-Chair.

Prof. Naish's research centers on contemporary climate change, especially the contribution of the polar ice sheets and global sea-level change, and improving sea-level projections. He leads the "Ice-Ocean-Atmosphere National Research Programme" in Antarctica New Zealand, and has made 13 expeditions to Antartica.

Prof. Stan's research interests include climate modeling with a focus on large-scale dynamics and predictability of tropical and midlatitute variability. She studies the role of cloud representation in modeling tropical cyclone activity, monsoon circulations, Madden-Julian Oscillation, and ENSO under current conditions and future climate change scenarios, among other topics.

New BSRN Leadership

The Baseline Surface Radiation Network (BSRN), which provides worldwide radiative flux measurements to validate satellite-based measurements, welcomes new leadership. Laura Riihimaki is the new Project Manager, replacing Christian Lanconelli, and Shun Sasaki is the new Deputy Project Manager.

Laura Riihimaki has been working with the National Oceanic and Atmospheric Administration (NOAA) Global Monitoring Laboratory for 6 years, as a University of Colorado CIRES employee for the first 5.5 years and as a NOAA employee for the last few months. She has been working with long-term surface radiation measurements since her graduate studies in 2004, and is excited to contribute to the leadership of BSRN. She considers it an honor to be part of such a high-quality global network with a community that has such a depth of expertise.

Shun Sasaki has been working at the Aerosol and Radiation Section of Japan Meteorological Agency (JMA) and operating Japanese BSRN stations to enrich the network in the northwestern Pacific area. He organized the World Meteorological Organization (WMO) Regional Pyrheliometer Comparison in Asia in 2023 and hosted the 18th BSRN meeting in Tokyo in July 2024. He'd like to work to improve BSRN data quality based on his experiences in radiation measurement area.

In Memoriam: Linda Mearns

Xubin Zeng, GEWEX SSG Co-Chair

Dr. Linda Mearns passed away on January 23, 2025 of pancreatic cancer. She was a National Science Foundation (NSF) National Center for Atmospheric Research (NCAR) Distinguished Scholar and a member of the GEWEX Scientific Steering Group (SSG). Linda was a thought leader in interdisciplinary climate change research for more than 40 years. She was renowned in regional climate-change, climate-change scenario formation, quantifying uncertainties, and climate-change impacts on agro-ecosystems at NCAR since 1982. More importantly, Linda served as a leader and inspiration to a generation of scientists, particularly women scientists at NCAR and beyond. Her contributions to the Intergovernmental Panel on Climate Change (IPCC) are substantial, including authoring reports in 1995, 2001, 2007, 2013/14 and 2021/22, both in Working Groups I and II Assessments.

2025 GEWEX Ambassadors

Congratulations to our two new GEWEX Ambassadors, Dr. Irina Sandu and Prof. Germán Poveda!

Irina Sandu, Director of the EU Destination Earth initiative at the European Centre for Medium-Range Weather Forecasts (ECMWF), has been involved in GEWEX in a variety of ways over the years. She led model intercomparison projects, including one on surface drag and momentum transport, and served as a Global Atmospheric System Studies (GASS) Panel member from 2018–2022.

Germán Poveda of the Universidad Nacional de Colombia (UNAL) in Medellín, Colombia is the first GEWEX Ambassador hailing from Latin America, and has long been involved in GEWEX. He was a member of the Scientific Steering Group from 2016–2024, and was a founding co-chair of ANDEX, the Regional Hydroclimate Project for the Andes.

We thank them for their ongoing commitment to GEWEX, and are honored to have them represent and promote the community.

Global Flood Crosscutting Initiative's Monthly Meetings

The Global Flood Crosscutting (CC) Initiative allows the GEWEX Hydroclimatology Panel (GHP) to propagate flood modeling and research knowledge from one region to another and synthesize results worldwide. The goal of this initiative is to identify opportunities where global collaborations can advance more approaches to understand flood consequences and identify the data, research infrastructure, and initiatives necessary for impactful partnership on this subject. To help this initiative, join our monthly meeting, discuss your ideas, and engage with the community. We will meet the first Friday of each month at 9 am EDT. Sign up for the mailing list to get the links to the meetings at *https://www.gewex.org/floods-cc/*. Recordings of the monthly meetings are available at *https://www.youtube.com/@GEWEX_WCRP/videos*, and a playlist can be found at *https://www.youtube.com/@GEWEX_WCRP/playlists*.

The River Experiment Initiative: Advancing Global Surface Water Science for Local Societal Benefits

Cédric H. David[1], Augusto Getirana[2,3], Peirong Lin[4], Simon Munier[5], Guy Schumann[6], Dai Yamazaki[7], Paul Bates[8], R. Edward Beighley[9], Sylvain Biancamaria[10], Aaron Boone[5], Vincent Fortin[11], Hyungjun Kim[12], Rodrigo Paiva[13], Ming Pan[14], Tamlin Pavelsky[15], Jan Polcher[16], Ahmad Tavakoly[17], Hind Oubanas[18], Sly Wongchuig[10], Fabrice Papa[10], Simon Mischel[19], Mohammad J. Tourian[20], Arnaud Cerbelaud[1], Jeffrey Wade[1], Manu Tom[1], Ali Nazemi[21], Paola Arias[22], and Peter Van Oevelen[23]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA; [2]NASA Goddard Space Flight Center, Greenbelt, MD, USA; [3]Science Applications International Corporation, Greenbelt, MD, USA; [4]Institute of Remote Sensing and GIS, School of Earth and Space Sciences, Peking University, Peking, China; [5]CNRM, Météo-France/CNRS, Université de Toulouse, Toulouse, France; [6]RSS-Hydro, Kayl, Luxembourg; [7]Institute of Industrial Science, University of Tokyo, Tokyo, Japan; [8]University of Bristol, Bristol, UK; [9]Northeastern University, Boston, MA, USA; [10]Laboratoire d'Études en Géophysique et Océanographie Spatiales, Toulouse, France; [11]Environment and Climate Change Canada, Dorval, QC, Canada; [12]Korea Advanced Institute of Science & Technology, Daejeon, South Korea; [13]Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil; [14]Center for Western Weather and Water Extremes, University of San Diego, La Jolla, CA, USA; [15]University of North Carolina Chapel Hill, Chapel Hill, NC, USA; [16]Laboratoire de Météorologie Dynamique, Palaiseau, France; [17]Engineer Research and Development Center, U.S. Army Corps of Engineers, Vicksburg, MS, USA; [18]Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement, Montpellier, France; [19]Global Runoff Data Centre, Koblenz, Germany; [20]Institute of Geodesy, University of Stuttgart, Stuttgart, Germany; [21]Department of Building, Civil and Environmental Engineering, Concordia University, Montreal, Quebec, Canada; [22]Universidad de Antioquia, Medellín, Antioquia, Colombia; [23]George Mason University, Fairfax, VA, USA

The writing is on the proverbial wall for Earth's freshwater stores: ice sheets are melting (Shepherd et al., 2012), aquifers are emptying (Famiglietti, 2014), reservoirs are drying (Yao et al., 2023), and glaciers are losing mass (Gardner et al., 2013), with varied implications for endorheic and exoreic basins around the world. Our "working capital" of freshwater is changing, therefore challenging the human right to safe and clean water for drinking and sanitation (United Nations, 2010) for the world's rapidly growing population. These trends may lead to an increasing reliance on other freshwater sources. While Earth's rivers have a tiny storage, their mighty flow makes them the most renewable and most accessible and hence most sustainable (Oki and Kanae, 2006) source of freshwater. The management of our freshwater portfolio may very well gradually include a "cash flow" perspective using this sustainable freshwater source. The powerful flow of rivers is also a great cause for concern because floods are consistently among the world's most disastrous natural hazards, ranking first in the number of events and in the number of people affected, second in economic cost, and fourth in total deaths (United Nations Office for Disaster Risk Reduction, 2020). Yet surprisingly little is known about spatiotemporal variations of global surface water stores and fluxes, induced by both natural and anthropogenic processes (Cooley et al., 2021; Bonnema et al., 2022).

Earth's rivers and lakes are currently facing pressing environmental and societal challenges. Extreme flood events are expected to increase with a changing climate (Milly et al., 2002), hence leading to devastating damages to human life, assets, and property, further aggravated by human development on floodplains. Water resources and river biodiversity are threatened by human population growth and global environmental change (Vorosmarty et al., 2010). The administration of transboundary basins is increasingly challenging as water management is largely impacted by drivers such as historical, legal, economic, and cultural differences, which could create or increase geopolitical tensions among neighbor nations (UNEP, 2016). Nutrient exports through rivers are primarily responsible for dead zones in the coastal oceans (Diaz and Rosenberg, 2008). River deltas are increasingly vulnerable to coastal hazards as declining sediment supply and climate change alter their sediment budgets (Nienhuis et al., 2020).

Even though access to recent in situ observational data of rivers is known to be globally declining (The Ad Hoc Group et al., 2001) due to lack of sharing, operational expense, and political instability (Fekete et al., 2015), some critical data sets are available (The Global Runoff Data Centre, 2023). In addition to in situ measurements, river systems can also be observed using spaceborne remote sensing and existing technology allows for measurements of water quantity (Smith, 1997) and water quality (Swain and Sahoo, 2017). Space agencies around the world have recognized the importance of Earth's rivers and lakes, and myriad current and upcoming satellites are either specifically designed to observe rivers or are capable of doing so. Radar nadir altimetry missions, such as the Topography Experiment (TOPEX)/Poseidon, Jason-1, Jason-2, Jason-3, and Sentinel 6 series or the European Remote-Sensing Satellite (ERS)-1, ERS-2, Envisat, Satellite with ARGOS and ALTIKA (SARAL), and Sentinel 3 series, initially designed to measure ocean levels, have shown their usefulness in monitoring inland waters globally (Crétaux et al., 2011; Schwatke et al., 2015). Optical satellites like Landsat and Sentinel 2 and synthetic aperture radars like Sentinel 1 and the National Aeronautics and Space Administration (NASA)-Indian Space Research Organization (ISRO) Synthetic Aperture Radar (NISAR) are also being combined to provide surface water extents (Bato et al., 2022). The Surface Water and Ocean Topography (SWOT) mission, launched in December 2022, is the first satellite mission specifically designed to observe global inland water dynamics (Durand et al., 2023). The unprecedented type, extent, and amount of data being acquired by SWOT could become a gamechanger in modern surface water sciences.

Multiple existing river models applicable at continental to global scales have been developed in the past two decades. The current generation of models includes–among others–Catchment-Based Macroscale Floodplain (CaMa-Flood; Yamazaki et al., 2011), Centre National de Recherches Météorologiques (CNRM) Total Runoff Integrating Pathways (CTRIP; Munier and Decharme, 2022), Hillslope River Routing (HRR; Beighley et al., 2009), Hydrological Modeling and Analysis Platform (HyMAP; Getirana et al., 2012), LISFLOOD-FP (Bates and Roo, 2000), Modelo de Grandes Bacias (MGB; Pontes et al., 2017), Organizing Carbon and Hydrology In Dynamic Ecosystems (ORCHIDEE; Polcher et al., 2011), and Routing Application for Parallel computatIon of Discharge (RAPID; David et al., 2011). Despite the demonstrated existing strengths of these numerical models, the state of global river modeling is currently insufficient to leverage existing global observations, particularly with respect to a comprehensive evaluation of how human interventions (e.g., dam building, reservoir operation, flood control structures, and water withdrawal) alter the spatiotemporal variability of surface waters (Harding et al., 2015). In addition, and although progress has been made on the integration of satellite data at the regional scale (Emery et al., 2020a; Revel et al., 2019; Pedinotti et al., 2014; Emery et al., 2020b; Paiva et al., 2013; Getirana et al., 2013; Wongchuig et al., 2024), ingesting spaceborne river data at the global scale, especially with the deluge of SWOT data, is still a challenge.

While intercomparison and benchmarking of land surface and climate models have been well-established in the past three decades (Henderson-Sellers et al., 1993; Boone et al., 2004; Meehl et al., 1997; Meehl et al., 2007), river models and their evaluation are still in drastic need of standardization. Recent river modeling efforts have been made to quantify streamflow accuracy as a function of total runoff boundary condition uncertainties (Getirana et al., 2014; Getirana et al., 2017; David et al., 2019), parameterization uncertainties (Yamazaki et al., 2011; Getirana et al., 2013; Decharme et al., 2012) , and anthropogenic effects (Hanasaki et al., 2006; Hanazaki et al., 2022; Tavakoly et al., 2023; Getirana et al., 2023; Dalcin et al., 2023; Sadki et al., 2023). However, due to conceptual and structural differences such as model discretization and numerical representation of natural and anthropogenic processes, the scientific community still lacks standardizations allowing for the objective comparison of river models, hence hindering their adoption into decision support activities.

Here, we propose establishing a common strategy for comparing river models called the GEWEX Hydroclimatology Panel (GHP) River Experiment (RivEx) Crosscutting initiative to strengthen our modeling systems and eventually facilitate their integration into local and regional decision-support activities, hence capitalizing on observational investments–both in situ and remote–and their impact on scientific discovery and societal applications. Specifically, we plan for the initiation of a dedicated data gathering and model comparison campaign that leverages the past two decades of progress in surface water modeling and remote sensing to provide physical constraints on the joint monitoring, understanding, and prediction of Earth's surface water cycle. Anthropogenic pressures on global surface water and their associated climate feedback have the potential to be better resolved through these activities, promoting linkage between modern water science and contemporary human societal needs.

We raise the following questions to receive the highest priorities as part of RivEx activities:

1. What is the current state of surface water modeling capabilities? When, where, and why do models perform well or fail to perform?
2. What are the hotspots of anthropogenic influences on global surface water, and can their footprint be accounted for in models?
3. How can global hydrological models be enhanced to ingest an increasing number of observations for more accurate reproduction of surface water stores and fluxes with relevancy at local and regional levels?

We anticipate that the initial RivEx activities will span over 36 months in two consecutive phases. Phase A (18 months) would produce a common and consistent data set of model inputs, model parameters, and hydrographic descriptions of the land surface, as well as a set of common metrics for model evaluation. Phase B (18 months) would follow with the implementation of multiple models and their joint evaluation.

Figure 1 (see cover) presents a schematic view of the RivEx initiative, highlighting its integration of in situ and remote observations across global to local scales to improve its process understanding and spatiotemporal characterization, aiming to eventually better serve local decision support.

The proposed activity directly aligns with two of the three GEWEX Science Goals (GEWEX, 2021). For Goal 1 (G1), "Determining the extent to which Earth's water cycle can be predicted", we aim for quantifiable progress at fine spatiotemporal scales on two of the subgoals: G1.1 ("Stores") and G1.2 ("Fluxes"), focusing on continental surface waters. For Goal 3 (G3), "Quantify anthropogenic influences on the water cycle and our ability to understand and predict changes to Earth's water cycle", our efforts align with subgoals G3.1 ("Anthropogenic forcing of continental scale water availability"), G3.2 ("Water management influences"), and G3.3 ("Variability and trends of water availability"). As the terrestrial hydrological cycle undergoes perturbations from human activities such as water withdrawals and irrigation, anthropogenic construction (e.g., dams, dikes), and floodplain urbanization, the magnitude, timing, and statistical distribution of surface water quantities are being modified. The accurate prediction of stores and fluxes at fine spatiotemporal scales is becoming an increasing challenge when using traditional modeling approaches without fusion of observations. By proposing community activities to ingest novel river, lake, and reservoir observations into numerical models at unprecedented spatiotemporal coverage and resolution, we aim to improve the quantification of the rate of change in global surface water networks. Our activities would directly contribute to understanding the space-time characteristics along natural and anthropogenic drivers. Such new approaches are essential for making substantial progress toward improving the predictability of such changes. In addition, the proposed activity also involves producing a consistent set of new data and metrics, which will be instrumental in evaluating to what extent anthropogenic activities changed surface waters from local to continental scales. Although indirectly related, the proposed activity may also impact GEWEX Science Goal 2, "Quantify the inter-relationships between Earth's energy, water, and carbon cycles to advance our understanding of the system and our ability to predict it across scales". For example, evapotranspiration is the most uncertain flux connecting energy, water, and carbon cycling, but it is not a directly observable quantity at macroscale. Likewise, runoff is not observable at continental to global scales. An accurate depiction of global surface water across scales can be used to constrain evapotranspiration and runoff more widely than before, and hence constrain both water-energy and water-carbon cycling processes.

We aim to promote an inclusive environment. Within the general scope envisioned, we welcome inclusion of all ideas, individuals, and communities that have not (yet) been involved.

References

Bates, P.D., and A.P.J.D. Roo, 2000. A simple raster-based model for flood inundation simulation. *J. Hydrol.* 236, 54–77.

Bato, G., et al., 2022. *Observational Products for End-Users from Remote Sensing Analysis (OPERA) Product Description.*

Beighley, R.E., et al., 2009. Simulating hydrologic and hydraulic processes throughout the Amazon River Basin. *Hydrol. Process.* 23, 1221–1235.

Bonnema, M., C.H. David, R.P. de M. Frasson, C. Oaida, and S.-H. Yun, 2022. The Global Surface Area Variations of Lakes and Reservoirs as Seen from Satellite Remote Sensing. *Geophys. Res. Lett.* 49, e2022GL098987.

Boone, A., et al., 2004. The Rhone-aggregation land surface scheme intercomparison project: An overview. *J. Clim.* 17, 187–208.

Cooley, S.W., J.C. Ryan, and L.C. Smith, 2021. Human alteration of global surface water storage variability. *Nature* 591, 78–81.

Crétaux, J.-F., et al., 2011. SOLS: A lake database to monitor in the Near Real Time water level and storage variations from remote sensing data. *Adv. Space Res.* 47, 1497–1507.

Dalcin, A.P., et al., 2023. The Role of Reservoir Reoperation to Mitigate Climate Change Impacts on Hydropower and Environmental Water Demands. *J. Water Resour. Plan. Manag.* 149, 04023005.

David, C.H., et al., 2011. River Network Routing on the NHDPlus Dataset. *J. Hydrometeorol.* 12, 913–934.

David, C.H., et al., 2019. Analytical Propagation of Runoff Uncertainty Into Discharge Uncertainty Through a Large River Network. *Geophys. Res. Lett.* 46, 8102–8113.

Decharme, B., et al., 2012. Global off-line evaluation of the ISBA-TRIP flood model. *Clim. Dyn.* 38, 1389–1412.

Diaz, R.J. and R. Rosenberg, 2008. Spreading Dead Zones and Consequences for Marine Ecosystems. *Science* 321, 926.

Durand, M., et al., 2023. A Framework for Estimating Global River Discharge from the Surface Water and Ocean Topography Satellite Mission. *Water Resour. Res.* 59, e2021WR031614.

Emery, C.M., et al., 2020a. Discharge Estimation via Assimilation of Multisatellite-Based Discharge Products: Case Study Over the Amazon Basin. *IEEE Geosci. Remote Sens. Lett.* 1–5.

Emery, C.M., et al., 2020b. Underlying Fundamentals of Kalman Filtering for River Network Modeling. *J. Hydrometeorol.* 21, 453–474.

Famiglietti, J.S., 2014. The global groundwater crisis. *Nat. Clim Change* 4, 945–948.

Fekete, B.M., et al., 2015. Time for in situ renaissance. *Science* 349, 685.

Gardner, A.S., et al., 2013. A Reconciled Estimate of Glacier Contributions to Sea Level Rise: 2003 to 2009. *Science* 340, 852–857.

Gardner, A.S., et al., 2013. A Reconciled Estimate of Glacier Contributions to Sea Level Rise: 2003 to 2009. *Science* 340, 852–857.

Getirana, A., A. Boone, and C. Peugeot, 2017. Streamflows over a West African Basin from the ALMIP2 Model Ensemble. *J. Hydrometeorol.* 18, 1831–1845.

Getirana, A.C.V., A. Boone, D. Yamazaki, and N. Mognard, 2013. Automatic parameterization of a flow routing scheme driven by radar altimetry data: Evaluation in the Amazon basin. *Water Resour. Res.* 49, 614–629.

Getirana, A., et al., 2023. Climate and Human Impacts on Hydrological Processes and Flood Risk in Southern Louisiana. *Water Resour. Res.* 59, e2022WR033238.

Getirana, A.C.V., et al., 2012. The Hydrological Modeling and Analysis Platform (HyMAP): Evaluation in the Amazon Basin. *J. Hydrometeorol.* 13, 1641–1665.

Getirana, A.C.V. et al., 2014. Water Balance in the Amazon Basin from a Land Surface Model Ensemble. *J. Hydrometeorol.* 15, 2586–2614.

GEWEX, 2021. Global Energy and Water EXchanges (GEWEX) Science Plan (2023–2032). WCRP Publication 9/2021, 12 pp. *https://www.gewex.org/gewex-content/uploads/2022/11/GEWEX-science-plan-v8.pdf*.

Hanasaki, N., S. Kanae, and T. Oki, 2006. A reservoir operation scheme for global river routing models. J. Hydrol. 327, 22–41.

Hanazaki, R., D. Yamazaki, and K. Yoshimura, 2022. Development of a Reservoir Flood Control Scheme for Global Flood Models. *J. Adv. Model. Earth Syst.* 14, e2021MS002944.

Harding, R., J. Polcher, A. Boone, M. Ek, and H. Wheater, 2015. Anthropogenic Influences on the Global Water Cycle - Challenges for the GEWEX Community. *GEWEX Q. Newsl.* 27, 6–8.

Henderson-Sellers, A., Z.L. Yang, and R.E. Dickinson, 1993. The Project for Intercomparison of Land-Surface Parameterization Schemes. *Bull. Am. Meteorol. Soc.* 74, 1335–1349.

Meehl, G.A., et al., 2007. THE WCRP CMIP3 Multimodel Dataset: A New Era in Climate Change Research. *Bull. Am. Meteorol. Soc.* 88, 1383–1394.

Meehl, G.A., G.J. Boer, C. Covey, M. Latif, and R.J. Stouffer, 1997. Intercomparison makes for a better climate model. *Eos Trans. Am. Geophys. Union* 78, 445–451.

Milly, P.C.D., R.T. Wetherald, K.A. Dunne, and T.L. Delworth, 2002. Increasing risk of great floods in a changing climate. *Nature* 415, 514–517.

Munier, S., and B. Decharme, 2022. River network and hydro-geomorphological parameters at 1⁄12° resolution for global hydrological and climate studies. *Earth Syst Sci Data* 14, 2239–2258.

Nienhuis, J.H., et al., 2020. Global-scale human impact on delta morphology has led to net land area gain. *Nature* 577, 514–518.

Oki, T., and S. Kanae, 2006. Global Hydrological Cycles and World Water Resources. *Science* 313, 1068–1072.

Paiva, R.C.D., et al., 2013. Assimilating in situ and radar altimetry data into a large-scale hydrologic-hydrodynamic model for streamflow forecast in the Amazon. *Hydrol Earth Syst Sci* 17, 2929–2946.

Pedinotti, V., A. Boone, S. Ricci, S. Biancamaria, and N. Mognard, 2014. Assimilation of satellite data to optimize large-scale hydrological model parameters: A case study for the SWOT mission. *Hydrol Earth Syst Sci* 18, 4485–4507.

Polcher, J., et al., 2011. Hydrological modelling on atmospheric grids: Using graphs of sub-grid elements to transport energy and water. *Geosci Model Dev* 16, 2583–2606.

Pontes, P.R.M., et al., 2017. MGB-IPH model for hydrological and hydraulic simulation of large floodplain river systems coupled with open source GIS. *Environ. Model. Softw*. 94, 1–20.

Revel, M., D. Ikeshima, D. Yamazaki, and S. Kanae, 2019. A Physically Based Empirical Localization Method for Assimilating Synthetic SWOT Observations of a Continental-Scale River: A Case Study in the Congo Basin. *Water* 11.

Sadki, M., S. Munier, A. Boone, and S. Ricci, 2023. Implementation and sensitivity analysis of the Dam-Reservoir OPeration model (DROP v1.0) over Spain. *Geosci Model Dev* 16, 427–448.

Schwatke, C., D. Dettmering, W. Bosch, and F. Seitz, 2015. DAHITI – an innovative approach for estimating water level time series over inland waters using multi-mission satellite altimetry. *Hydrol Earth Syst Sci* 19, 4345–4364.

Shepherd, A., et al., 2012. A Reconciled Estimate of Ice-Sheet Mass Balance. *Science* 338, 1183–1189.

Smith, L.C., 1997. Satellite remote sensing of river inundation area, stage, and discharge: A review. *Hydrol. Process*. 11, 1427–1439.

Swain, R., and B. Sahoo, 2017. Improving river water quality monitoring using satellite data products and a genetic algorithm processing approach. *Sustain. Water Qual. Ecol*. 9–10, 88–114.

Tavakoly, A.A., C.H. David, J.L. Gutenson, M.W. Wahl, and M. Follum, 2023. Development of non-data driven reservoir routing in the routing application for parallel computatIon of discharge (RAPID) model. *Environ. Model. Softw*. 161, 105631.

The Ad Hoc Group et al., 2001. Global water data: A newly endangered species. *Eos Trans. Am. Geophys. Union* 82, 54–58.

The Global Runoff Data Centre, 2023. *GRDC Data Portal*. https://portal.grdc.bafg.de/applications/public.html?publicuser=PublicUser.

United Nations, 2010. *Resolution 64/292: The Human Right to Water and Sanitation*.

United Nations Environment Programme (UNEP), 2016. *Transboundary River Basins Status and Trends, Summary for Policy Makers, Volume 3, River Basins*.

United Nations Office for Disaster Risk Reduction, 2020. *The Human Cost of Disasters: An Overview of the Last 20 Years (2000–2019)*.

Vorosmarty, C.J., et al., 2010. Global threats to human water security and river biodiversity. *Nature* 467, 555–561.

Wongchuig, S., et al., 2024. Multi-Satellite Data Assimilation for Large-Scale Hydrological-Hydrodynamic Prediction: Proof of Concept in the Amazon Basin. *Water Resour. Res*. 60, e2024WR037155.

Yamazaki, D., S. Kanae, H. Kim, and T. Oki, 2011. A physically based description of floodplain inundation dynamics in a global river routing model. *Water Resour. Res*. 47, W04501.

Yao, F., et al., 2023. Satellites reveal widespread decline in global lake water storage. *Science* 380, 743–749.

Excessive Tibetan Plateau Spring Warming Found to Cause Catastrophic June 2024 Precipitation in Southern China and Bangladesh—A Typical LS4P Scenario

Yongkang Xue[1] and Aaron Boone[2]

[1]University of California, Los Angeles (UCLA), USA; [2]CNRM, Université de Toulouse, Météo-France, CNRS, France

In June 2024, relentless deadly rainfall lashed southern China and Bangladesh, threatening millions with severe flooding. The precipitation in the Yangtze River Basin from June 10th to 30th was about 50% above the long-term average, making June 2024 the wettest June in Southern China since 1980. The events drew worldwide attention due to their devastating societal and economic impacts (Figures 1, 2c).

No operational season prediction forecast system in the world predicted or simulated such extreme events last year. For instance, since sea surface temperature (SST) is traditionally considered as a key factor in climate and weather predictions, we tested the effect of May and June SST on the June 2024 events using the National Center for Environmental Research (NCEP) Global Forecast System (GFS) coupled with the Simplified Simple Biosphere Model (SSiB) land model (GFS/SSiB). We found that SST attributed only 17% of the observed rainfall anomaly in Southern China, and no heavy rainfall in Bangladesh was predicted (Li et al., 2025). There was no plausible explanation being openly proposed in the scientific community and reported in public for the events until the GEWEX initiative Impact of Initialized Land Surface Temperature and Snowpack on Subseasonal-to-Seasonal Prediction (LS4P, Xue et al., 2021) organized a study to explore the cause and mechanisms (Li et al., 2025). LS4P aims to explore a new approach for subseasonal-to-seasonal (S2S) prediction by utilizing spring land surface temperature/subsurface temperature (LST/SUBT) anomalies over high-elevation regions such as the Tibetan Plateau (TP) and the Rocky Mountains to predict late spring and summer downstream droughts or floods.

Since 2018, LS4P has conducted a series of investigations to identify a lagged relationship between spring land temperatures over the TP and Rocky Mountains and downstream summer precipitation over East Asia, North America, and other regions. Specifically, the findings indicated that when the TP experiences a warm or cold spring, southern China is likely to experience a wet or dry summer, respectively (Xue et al., 2022, 2024). In June 2024, as record-breaking rainfall began to develop in Southern China, LS4P scientists found excessively warm TP spring land temperatures, which were the warmest since 1980, and hypothesized the heavy June rainfall in Southern China was a typical scenario, established in previous LS4P findings (Xue et al., 2022, 2024). During the LS4P Side Meeting at the 2024 GEWEX Open Science Conference (July 7–12) in Sapporo, Japan, a group of LS4P scientists volunteered to collaborate on an investigation of the cause of the June 2024 extreme event in near real-time, aim-

***Figure 1**. Relentless deadly June 2024 rainfall lashes southern China and Bangladesh as flooding threatens millions. Left and middle panels from China Hunan Meteorology; right panel from the* Dhaka Tribune

ing to provide a timely explanation to both the scientific community and the public.

Using the same atmosphere-land coupled model (i.e., the GFS/SSiB) for the SST study, near real-time experiments were conducted. The National Oceanic and Atmospheric Administration (NOAA) database provided timely initial and boundary conditions for the model simulations. However, the original model simulation was unable to reproduce the observed 2-m surface temperature (T-2m) anomalies over the TP and the extreme June precipitation. One of the biggest challenges in this study was to reproduce the observed extreme warm temperatures over the TP. LS4P Phase I (LS4P-I) research had previously shown that both global models and reanalysis data sets (which provide atmospheric and surface initial conditions for global models) systematically failed to capture May temperature anomalies over the TP, leading to underestimation of anomalous June rainfall in Southern China and exhibiting severe biases (Xue et al., 2021).

To address this, we adopted a land-state initialization approach, developed in LS4P-I and based on the observed T-2m anomaly and model biases over the TP (Xue et al., 2021). This approach successfully reproduced most of the observed May 2024 T-2m anomalies over the TP (Figures 2a and 2b): the model simulated approximately 55% of the observed extreme June rainfall anomaly in Southern China (Figures 2c and 2d). Moreover, the experiment realistically simulated the observed precipitation anomalies over other regions. Notably, about 90% of the observed heavy rainfall in Bangladesh was simulated—an important outcome, as Bangladesh experienced devastating June floods with widespread media coverage that reported an initially unclear cause. In addition, abnormally wet conditions over the eastern TP and southern Japan, and dry conditions over northern China, were also captured in the simulation (Figure 2d), which were consistent with the observations (Figure 2c).

The results over Southern China and Bangladesh passed a more stringent field significance test, which accounts for multiplicity and spatial correlation effects, indicating that these results did not occur by chance. A detailed discussion on these results was published in Science Bulletin (Li et al., 2025). The LS4P scientists finished the experiments in August 2024 and submitted the paper in September. The paper was accepted in December and published in January 2025. It typically takes years to identify the causes of climate-related catastrophic events. Our ability to determine the primary driver of the June 2024 extreme summer hydroclimate event in such a short timeframe underscores the robustness of the LS4P approach. A schematic diagram was developed to illustrate how subseasonal processes, influenced by remote TP spring land temperature anomalies, affect downstream summer precipitation (Li et al., 2025). This synthesis integrates findings from both this study and LS4P's previous comprehensive analyses (Xue et al., 2024).

S2S precipitation prediction skill has remained stubbornly low for years for late spring and summer, which encompasses a substantial number of extreme hydroclimate events. To tackle this challenge, the World Meteorological Organization (WMO) launched the S2S Prediction Project, which focuses on improving predictions for timescales ranging from 2 weeks to 3 months. Among various influencing factors, the combined effect of land initialization and configuration have been identified as one of the key elements with the potential to significantly enhance S2S predictions. While many land variables such as albedo, soil moisture, snowpack, and vegetation have been utilized for climate and weather predictions since the 1970s, the memory effect of land temperature on S2S predictions has been largely overlooked, despite the fact that the T-2m measurements have the highest quality among land variables, with the longest meteorological observational records, global coverage, and dense measurement networks.

The LS4P team, comprising leading climate and weather prediction and research centers from many different countries, has made great strides in demonstrating the critical role of high-mountain land temperature anomalies in S2S predictions. The project has published numerous peer-reviewed papers and contributed to a special issue in *Climate Dynamics* titled "Sub-seasonal to Seasonal (S2S) predictability and Land-induced Forcing", featuring 17 papers. Supported by GEWEX, LS4P's accomplishments represent a major contribution to advancing S2S prediction—a field that is scientifically challenging, yet critically relevant to society. The LS4P S2S work opens new avenues for improving S2S prediction for operational applications, which is increasingly important

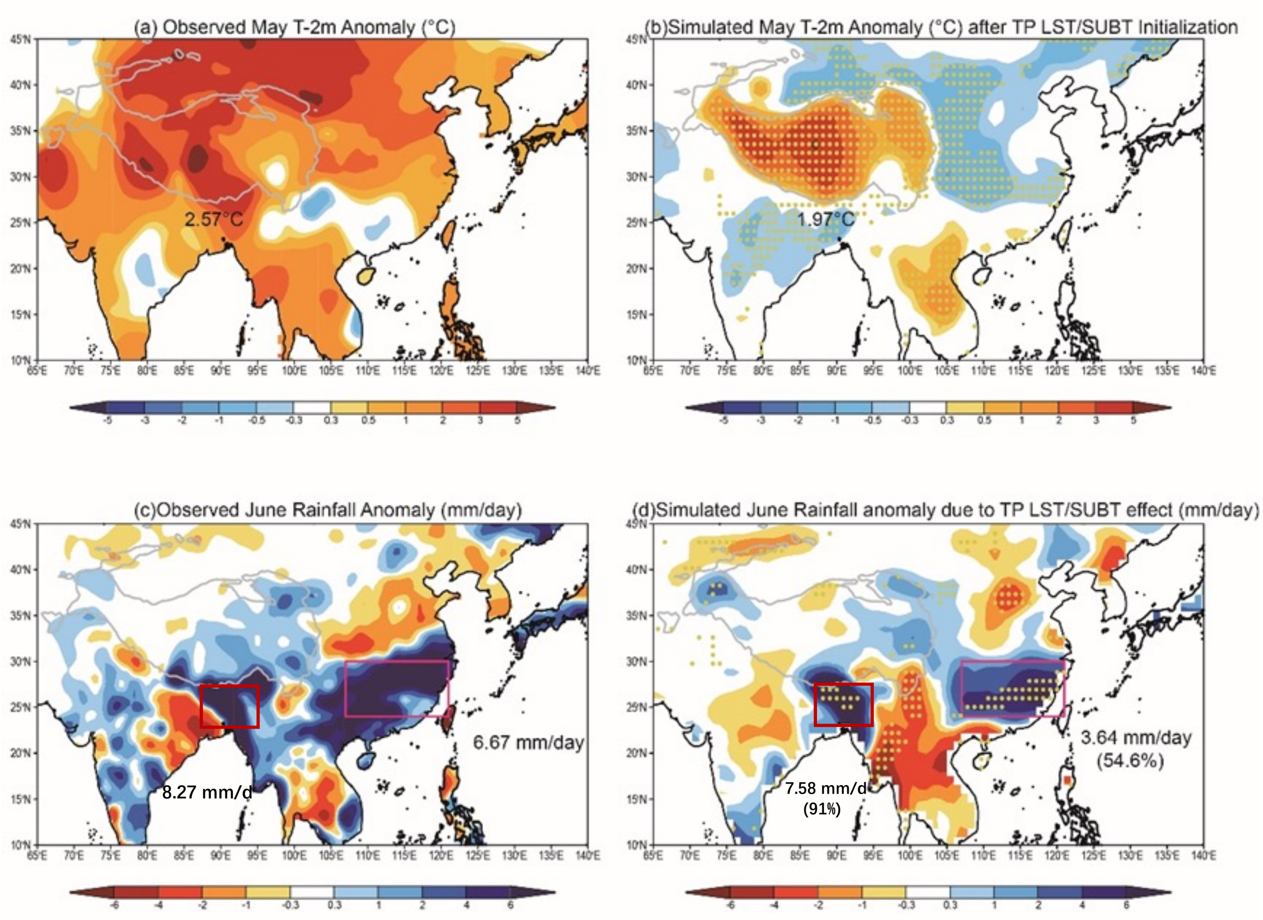


***Figure 2**. Observed and Simulated 2m-temperature (T-2m, °C) and precipitation (mm/day) anomalies. (a) Observed May T-2m anomaly; (b) GFS/SSiB2 simulated May T-2m anomaly after soil temperature initialization over TP. (c) same as (a), but for the June 2024 precipitation anomaly. (d) Simulated June precipitation anomaly due to TP LST/SUBT effect. Note: (1). The dotted grids denote the statistical significance based on the Student T-test at the p < 0.1 level. (2). The grey bold 4000m contour lines illustrate the approximate TP geographic location. (3). The numbers in panels are averages of corresponding variables over the TP in panels (a) and (b) and over the red box in panels (c) - (d). The values in parentheses in (d) indicate the percentage anomalies produced by TP LST/SUBT anomalies*

given the rising frequency of anomalous meteorological events observed worldwide.

LS4P is currently working on the Phase-II experiments, which explore the effect of LST/SUBT in both the Rocky Mountains and the TP on droughts and floods across North America, East Asia, and other regions. Preliminary results from a few LS4P groups suggest that spring LST/SUBT anomalies in these high-altitude regions influenced both the catastrophic 1998 summer flood in Southern China and the severe drought in the Southern Great Plains of the U.S. We welcome new research groups to join this effort.

Despite its promise, the LS4P approach has yet to gain full recognition within the broader scientific community, where traditional SST-based methods still dominate. However, the 2024 extreme rainfall study reinforces LS4P's validity (Xue et al., 2024), demonstrating that excessive TP spring warming was the primary factor behind the catastrophic June 2024 rainfall in Southern China and Bangladesh. While many unresolved challenges still remain with its new approach, the LS4P team hopes their paper in *Science Bulletin* will stimulate further research using diverse methodologies to enhance S2S prediction of extreme hydroclimate events and increase public awareness of the latest advancements in this field made by LS4P scientists.

References

Li, Q., Y. Xue, X. Kong, W. K.-M. Lau, A. Wang, Q.P. Li, Z. Cao, H. Nayak, G. Xu, W. Guo, and V. Ratko, 2025. Excessive Tibetan Plateau Spring Warming Found to Cause Catastrophic June 2024 Heavy Rainfall in China. *Sci. Bull.*, https://doi.org/10.1016/j.scib.2025.01.011.

Xue, Y., T. Yao, A.A. Boone, I. Diallo, Y. Liu, et al., 2021. Impact of Initialized Land Surface Temperature and Snowpack on Subseasonal to Seasonal Prediction Project, Phase I (LS4P-I): Organization and Experimental design. *Geosci. Model Dev.*, 14, 4465–4494, https://doi.org/10.5194/gmd-14-4465-2021.

Xue, Y., I. Diallo, A.A. Boone, T. Yao, Y. Zhang, et al., 2022. Spring Land Temperature in Tibetan Plateau and Global-Scale Summer Precipitation – Initialization and Improved Prediction. *Bull. Am. Meteorol. Soc.*, 103, 12, E2756–E2767, DOI: https://doi.org/10.1175/BAMS-D-21-0270.1.

Xue, Y., I. Diallo, A.A. Boone, Y. Zhang, X. Zeng, et al., 2024. Remote effects of Tibetan Plateau spring land temperature on global subseasonal to seasonal precipitation prediction and comparison with effects of sea surface temperature: The GEWEX/LS4P Phase I experiment. *Clim. Dyn.*, 62, 2603–2628, DOI: 10.1007/s00382-023-06905-5.

Satellite Hydrology for Advancing the Coupling between Earth's Water, Energy and Carbon Cycles: An Emerging Opportunity from the Earth Observation Science Strategy of the European Space Agency

Z. Su and Yijian Zeng
University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), The Netherlands

The Earth system functions through complex feedbacks and interconnections that collectively shape the Earth's environment, including its climate. Previous Earth Observation Science Strategies of the European Space Agency (ESA) focused on specific Earth system domains, emphasizing the derivation of essential observational variables. Such approaches are important and necessary because often certain critical variables are needed for monitoring and modeling certain Earth system components; however, they also lead to inconsistences when integrating different variables for detecting climate signals or identifying cross-domain feedbacks and interactions. Such a conundrum can only be ameliorated when we consider the Earth system as a whole, by monitoring and modeling the different components as a coherent system that properly includes the feedbacks and interconnections. The new Earth Observation Science Strategy (ESA, 2024) reflects such a shift in paradigm and includes six major thematic objectives: the water cycle, the carbon cycle and chemistry, energy fluxes, ecosystem health, extremes and hazards, as well as Earth system interfaces and coupling (see Figure 1). In addressing these thematic objectives, twenty-three science questions have been crafted to target key Earth system science issues and knowledge gaps (Styles et al., 2024), for which satellite technology provides unique contributions, leveraging current and emerging data sources and pioneering new space-based observations.

Key scientific questions identified by GEWEX (GEWEX, 2021; Stephens et al., 2023) have contributed to highlighting the central role of the water cycle and in formulating two scientific questions among the twenty-three in the new strategy:

Scientific Question-43*: What are the main coupling determinants between Earth's energy, water, and carbon cycles and how accurately can we predict the forcings and feedbacks between the different components of the Earth system?

The coupling of the energy and water cycles with the carbon cycle needs to be pursued by including the observation and description of photosynthesis as a major component of the whole system. This will enable us to close the water budget better over land, provide improved information for water availability and quality for decision making for water, energy and food security and for initializing and assessing climate predictions from sub-daily to multi-annual time scales and at the relevant adaptation scales (e.g., political and administrative regions). Photosynthesis is the physical process that couples energy, water, and carbon (and nutrient) fluxes, but current EO observation is insufficient to fully capture this coupling. The necessity for accurately describing photosynthesis and other processes involved in evaporation from bare soil and water surface by coupling energy, water, and carbon components and the necessary observables has been comprehensively outlined in recent studies (Wang et al., 2021; Zeng and Su, 2024; Zeng et al., 2024). Detecting and attributing past changes in the water cycle due to either the increased concentration of greenhouse gasses in the atmosphere or changes in land and water use will be essential to advance our prediction capability and tools (Stephens et al., 2023). New observational capability from space, in particular the capability to observe water potential gradients from soil through vegetation to the atmosphere, will greatly help resolve this scientific issue.

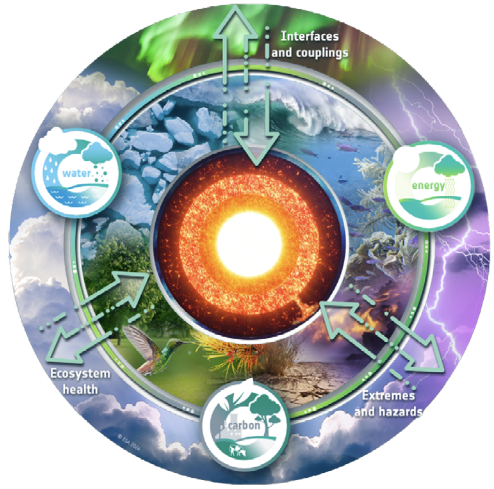


***Figure 1**. The interconnected nature of the Earth system and connections to the six overarching scientific themes (ESA, 2024)*

Scientific Question-44: How important are anthropogenic influences on the water cycle and how accurately can we predict anthropogenic influences on the water cycle?

The observation aspects for answering these questions can be achieved by observing the land cover changes (at the seasonal to annual scale), changes in water levels in lakes and man-made reservoirs (at daily to weekly and seasonal scales), as well as irrigated areas. It is possible to estimate the water used for irrigation by estimating the cumulative difference between evaporation and precipitation of an area, including the use of soil moisture observations to invert water balance if the region is irrigated by extracting groundwater. It has been demonstrated that Gravity Recovery and Climate Experiment (GRACE) observations can be linked to the depletion of groundwater levels for large regions (Rodell and Reager, 2023), which may help such assessments. Availability of management data and coupled modeling are other necessary means to fully resolve the above questions. Variability in mountain snow and glaciers due to anthropogenic influence (Gottlieb and Mankin, 2024) also exerts a critical impact on the water cycle. Snow melt and glacier meltwater support about two billion people worldwide (Mankin et al., 2015) and provide a critical source of runoff, particularly from mountain areas.

Progress towards solving these science questions of the water cycle requires the generation and exploitation of improved data sets of precipitation, evaporation and transpiration, river discharge, soil moisture, snowpack, surface water bodies, ground-

**The original numbering for the candidate scientific questions is retained for traceability* water, vegetation, and land use change data, among other information. This can be synchronized with advances in Earth system modeling across scales to move forward with the development of an integrated analysis of the water and energy exchanges within and between the atmospheric and continental reservoirs. Advances in these aspects directly contribute to our ability to devise adaptation strategies and to strengthen the resilience of our society to adverse impacts due to anthropogenic changes. Other factors that should be included are: agricultural water use by leveraging microwave soil moisture measurements to characterize irrigation areas and quantify water usage, and utilizing high spatial resolution satellite observations to more accurately capture human interventions in the water cycle.

The relevance of addressing these challenges to international treaties, agreements and conventions, as well as to national policies and their benefits to society, can be found in the new Earth Observation Science Strategy (ESA, 2024). Detailed technical approaches and resource requirements are outlined in Styles et al. (2024), particularly for Science Questions 43 and 44, presenting unique opportunities within this new strategy for advancing hydrology and Earth system sciences. We invite the GEWEX community to take notice of this new opportunity in developing science, technology, and applications that can confront the escalating threats posed by climate change, biodiversity loss, pollution, and extreme weather events to our society.

References

ESA, 2024. Earth Science in Action for Tomorrow's World – Earth Observation Science Strategy, European Space Agency, 42pp, October 2024. https://doi.org/10.5281/zenodo.13819557

GEWEX, 2021. Global Energy and Water EXchanges (GEWEX) Science Plan (2023-2032), WCRP Publication 9/2021, 12 pp. www.gewex.org/about/science/gewex-science-goals

Gottlieb, A.R., and J.S. Mankin, 2024. Evidence of human influence on Northern Hemisphere snow loss. *Nature*, 625(7994), pp.293–300

Mankin, J., D. Viviroli, D. Singh, A. Hoekstra, and N. Dienbaugh, 2015. The potential for snow to supply human water demand in the present and future. *Environ. Res. Lett.* 10 114016. DOI 10.1088/1748-9326/10/11/114016

Rodell, M., and J.T. Reager, 2023. Water cycle science enabled by the GRACE and GRACE-FO satellite missions. *Nat. Water*, 1(1), pp.47–59

Stephens, G., J. Polcher, X. Zeng, P. Van Oevelen, G. Poveda, et al., 2023. The First 30 years of GEWEX. *Bull. Am. Meteorol. Soc.*, 104(1), pp.E126–E157

Styles, J., S. Briggs, A. Bastos, M.-F. Buongiorno, D. Crisp, et al., 2024. *ESA Earth Observation Science Strategy–Guiding Science Questions,* Study Report, ESA Contract No 4000139664, September 2024. https://doi.org/10.5281/zenodo.13846926

Wang, Y., Y. Zeng, L. Yu, P. Yang, C. Van der Tol, Q. Yu, X. Lü, H. Cai, and Z. Su, 2021. Integrated modeling of canopy photosynthesis, fluorescence, and the transfer of energy, mass, and momentum in the soil–plant–atmosphere continuum (STEMMUS–SCOPE v1. 0.0). *Geosci. Model Dev.*, 14(3), pp.1379–1407.

Zeng, Y., and Z. Su, 2024. Digital twin approach for the soil-plant-atmosphere continuum: Think big, model small. *Front. Sci.*, 2, p.1376950.

Zeng, Y., A. Verhoef, H. Vereecken, E. Ben-Dor, T. Veldkamp, et al., 2024. Tracking Soil Health: Monitoring and Modeling the Soil-Plant System. *ESS Open Archive*. June 10, 2024. DOI: 10.22541/essoar.171804479.91646868/v1

Land's Contribution to Seasonal-to-Interannual Predictability of Extreme Events

L. Ruby Leung and Pengfei Shi
Pacific Northwest National Laboratory, Richland, WA, USA

Extreme events like heatwaves have captured global attention in recent years due to their devastating effects on human health, agriculture, and the environment. One of the most notorious examples is the 2003 European summer heatwave, which caused widespread fatalities, economic damage, and long-term ecological impacts. While such heatwaves are often attributed to local land-atmosphere conditions or remote ocean influences, our research (Shi et al., 2024) uncovers the surprising interannual predictability of this event and its attribution to the land conditions on the Tibetan Plateau (TP).

Known as the "Third Pole", the TP plays a significant role in shaping global weather patterns through its unique geographic and thermodynamic characteristics. Acting as a massive heat source at high altitudes, the TP influences the large-scale circulation patterns in the atmosphere, particularly during boreal summer. The plateau's ability to generate Rossby waves—large-scale atmospheric waves propagating across continents—connects the TP with distant regions, including Europe. While the current GEWEX project (Impact of Initialized Land Temperature and Snowpack on Sub-seasonal to Seasonal Prediction, LS4P) has demonstrated the impact of the TP surface temperature anomaly on monthly to seasonal prediction of global precipitation anomalies via the Rossby waves, the Tibetan Plateau-Rocky Mountain Circumglobal (TRC) wave train in particular (e.g., Xue et al., 2024 and references therein), our study (Shi et al., 2024) further uncovers how TP land conditions, especially its snow cover, contributed to the interannual predictability of the 2003 European summer heatwave that lasted for two months.

Using a newly-developed, weakly coupled land data assimilation system, we incorporated soil moisture and soil temperature from the Global Land Data Assimilation System (GLDAS) over the TP into a coupled climate model. Remarkably, our model hindcasts initialized from the balanced atmosphere, land, and ocean states from the coupled climate simulation with land data assimilation show substantial skill in predicting the 2003 European heatwave two years in advance, reproducing the large-scale temperature anomalies and high-pressure systems over Europe during that summer (Figure 1). This underscores the TP's significant influence on the atmospheric circulation patterns that drove the heatwave and demonstrates how local land states from the TP can enhance the predictability of such extreme events.

In our analysis, we found that the key mechanism linking the TP to the 2003 European heatwave lies in the snow cover anomalies over the TP, which are influenced by the assimilation of soil moisture and temperature. A reduction in spring

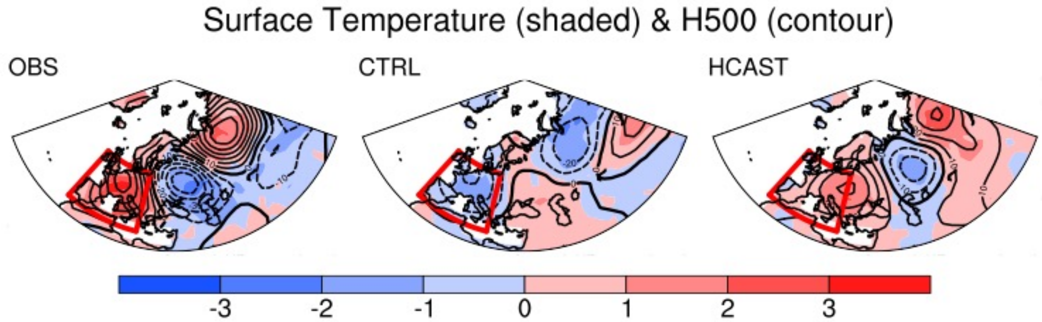


Figure 1. *Anomalies of the June–August 2003 European heatwave event for surface air temperature (shaded, units: °C) and 500-hPa geopotential height (contour, units: gpm). The control simulation (CTRL) is a free-running coupled simulation. The HCAST experiments were initialized between April 2000 and January 2001 from the coupled run assimilating monthly mean GLDAS data over the Tibetan Plateau. The anomalies are calculated by subtracting the climatology of 1996–2010. The red boxes show the European (10°W–20°E, 35°–55°N) region.*

snow cover over the TP in 2003 led to increased surface heating, which initiated a distinct Rossby wave train. This wave train propagated across Eurasia, ultimately generating high-pressure anomalies over Europe during the summer. The high-pressure system reduced cloud cover and increased net surface radiation, contributing to the extreme temperatures experienced during the heatwave. This physical process demonstrates the far-reaching impact of the TP's land conditions on the European climate, creating a favorable environment for extreme weather events.

Beyond its influence on atmospheric circulation, the TP also played a significant role in modulating ocean conditions during this period. By incorporating the TP's soil moisture and temperature in the coupled climate simulation through land data assimilation, the TP's land states affected sea surface temperatures (SST) in the Atlantic and Pacific Oceans, further enhancing the predictability of the 2003 European heatwave. Figure 2 shows the improved initial SST anomalies in January 2001 from the coupled run with land data assimilation due to the TP land processes' remote influence. By incorporating TP land data into our climate model, the cooling over the tropical Atlantic and tropical eastern Pacific are well captured to provide more realistic SST to initialize the hindcasts, demonstrating the TP's broader influence on both oceanic and atmospheric systems.

Although the societal benefits of seasonal-to-interannual forecasts of extreme events are well recognized, progress in improving such forecasts has been slow, particularly for regions beyond the tropics. Numerous studies have demonstrated the role of the oceans and modes of variability, such as the El Niño-Southern Oscillation (ENSO), as key sources of seasonal-to-interannual predictability. In contrast, land processes were thought to provide predictability mainly at subseasonal-to-seasonal timescales (e.g., Merryfield et al., 2020) because of the shorter memory of land compared to the ocean. This study has advanced a new understanding of the sources of climate predictability by demonstrating that land processes over the Tibetan Plateau can provide seasonal-to-interannual predictability for extreme events through their substantial teleconnection influence on the atmosphere and ocean. Our finding that land may provide predictability beyond a season through its remote influence on the oceans with longer memory opens new research venues to advance climate predictions, including predictions of extreme climatic events at seasonal-to-decadal (S2D) timescales. Notably, heating over the TP at high altitudes may effectively perturb atmospheric circulation in the upper troposphere with hemispheric-to-global impacts. To what degree the TP and other high mountains and even low-lying land regions, which could induce elevated heating through convection, provide S2D predictability should be systematically investigated in the future.

By showing skillful predictions using a weakly coupled land data assimilation system to provide well-balanced states for the atmosphere, land, and ocean to initialize coupled model hindcasts, our results underscore the importance of advancing coupled data assimilation systems for predictions of extreme events. This study also motivates more research to compare different initialization strategies, such as the use of coupled and uncoupled data assimilation and forced offline ocean/sea-ice and land simulations, for improving climate predictions. While decadal hindcast experiments have typically focused on the initialization of the ocean (e.g., Boer et al., 2016), our results suggest a potential synergistic role of the oceans and land in the predictability of the coupled climate system. Investigating the local and remote impacts of land processes and the synergistic influence of land and oceans on S2D climate predictions may provide a more holistic understanding of the sources of climate predictability, which could strengthen the foundation for improving early warning systems.

References

Boer, G.J., et al., 2016. The Decadal Climate Prediction Project (DCPP) Contribution to CMIP6. *Geosci. Model Dev.*, 9, 3751–3777, https://doi.org/10.5194/gmd-9-3751-2016.

Merryfield, W.J., et al., 2020. Current and Emerging Developments in Subseasonal to Decadal Prediction. *Bull. Am. Meteorol. Soc.*, 101, E869-E896, https://doi.org/10.1175/BAMS-D-19-0037.1.

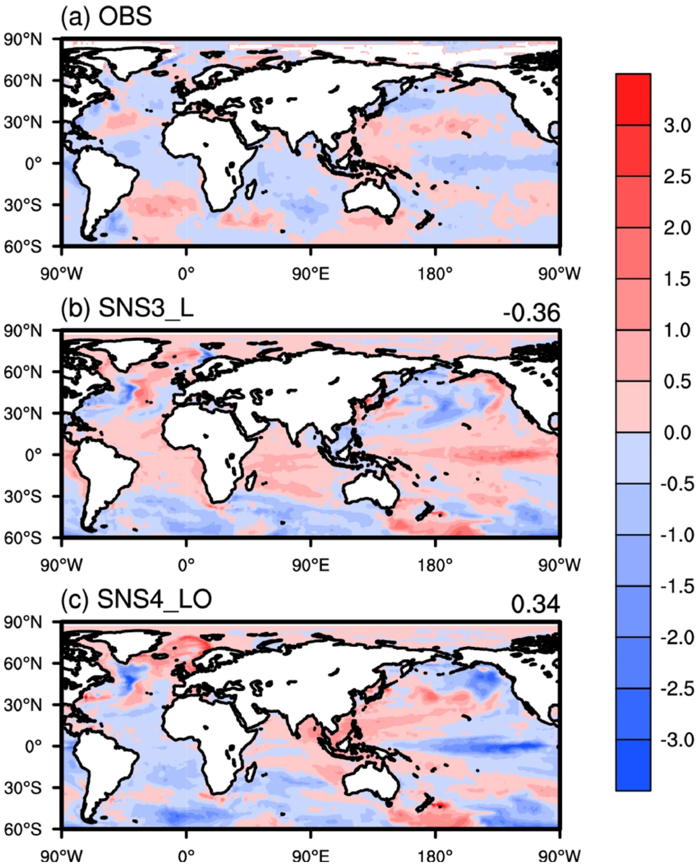


Figure 2. *Sea surface temperature (SST, units: °C) anomalies in January 2001 for (a) OBS, (b) SNS3_L, and (c) SNS4_LO for hindcasts initialized with the land and both the land and ocean states from the coupled run with assimilation of Tibetan Plateau land data, respectively. The Pearson Correlation Coefficient of the spatial pattern between observed and SST anomalies in SNS3_L and SNS4_LO over the global ocean is given at the top right corner for (b) and (c).*

Shi, P., L.R. Leung, H. Lu, B. Wang, K. Yang, and H. Chen, 2024. Uncovering the Interannual Predictability of the 2003 European Summer Heatwave Linked to the Tibetan Plateau. *NPJ Clim. Atmos. Sci.*, 7, 242, https://doi.org/10.1038/s41612-024-00782-3.

Xue, Y., et al., 2024. Remote effects of Tibetan Plateau spring land temperature on global subseasonal to seasonal precipitation prediction and comparison with effects of sea surface temperature: The GEWEX/LS4P Phase I experiment. *Clim. Dyn.*, 62, 2603-2628, DOI: 10.1007/s00382-023-06905-5.

Satellite Gravity Missions and GEWEX: Water Cycle Applications Perspective

Jürgen Kusche[1], Ilias Daras[2], John T. Reager[3], and Luca Brocca[4]

[1]University of Bonn, Germany; [2]ESA/ESTEC, The Netherlands; [3]NASA/JPL Pasadena, CA, USA; [4]CNR/Research Institute for Geo-Hydrological Protection, Perugia, Italy

Satellite Gravimetry and Water Storage

Different from all other remote sensing satellites, gravimetry satellites observe the changes in the water cycle through sensing tiny variations of the gravitational acceleration that water storage redistributions at the Earth's surface generate at the orbital altitude of a few hundreds of kilometers. The Gravity Recovery and Climate Experiment (GRACE) satellite mission, a joint project of the National Aeronautics and Space Administration (NASA) and the German Aerospace Center (DLR), launched in 2002 and measured data for approximately 15 years until it was replaced in 2018 by the successor GRACE Follow-On (GRACE-FO), a NASA and Germany's Helmholtz Centre for Geosciences (GFZ Potsdam) partnership. The two missions together have thus created 20+ years of global gravity field observations.

These satellite missions rely on extremely accurate distance measurements between identical polar-orbiting spacecraft, which are realized through a K-Band Ranging (KBR) system. GRACE-FO is additionally equipped with an experimental Laser Ranging Interferometer (LRI), which improves the precision of inter-satellite range measurements by a factor of at least ten. Gravity field solutions are subsequently then converted to mass variations, which enable the monitoring of changes in the hydrosphere, oceans, and interior of the Earth. The monthly data contribute to the quantification of climate-related trends, natural inter-annual variability, and human-induced effects in processes related to glacier melting, snowpack and groundwater volume changes, water deficits during droughts, and sea level rise due to ocean warming and mass influx. Monthly water-equivalent mass change maps, albeit restricted to a resolution of about 300 km in space, were quickly adopted in the hydrological and climate community and led to important initiatives within GEWEX.

Limitations and Requirements

However, GRACE-FO data are limited in terms of spatio-temporal resolution and latency. As demonstrated in an International Union of Geodesy and Geophysics (IUGG) report (Pail et al., 2015) and more recently in the European Space Agency (ESA) Quantum Space Gravimetry for monitoring Earth's Mass Transport Processes (QSG4EMT) survey (Eicker et al., 2024), future user needs in various fields, including water cycle research, indicate that improvements in both temporal and spatial resolution would be beneficial for a suite of science and user applications. What limits satellite gravimetry currently, next to the orbital coverage and in particular the errors in the

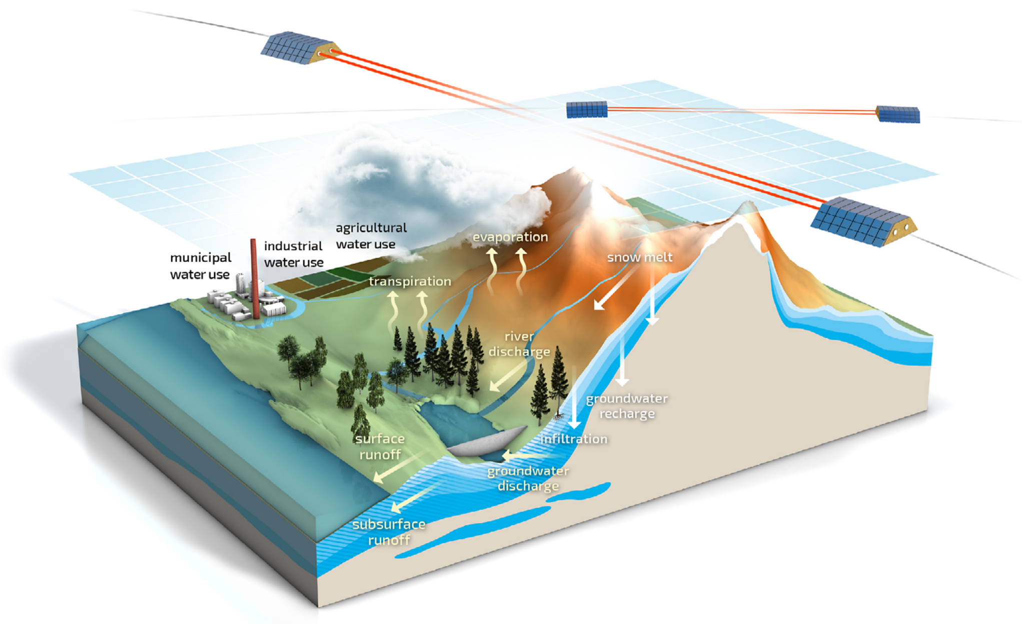


Figure 1. *MAGIC mission and related processes*

measurement of non-gravitational accelerations at low frequencies, is the large background of fast-changing mass signals in the atmosphere and the ocean that current global models and reanalyses do not capture appropriately. Despite removing such effects during the processing from modeling efforts, this leads to an aliasing of signals with a resulting distinct and complex error pattern superimposed on monthly maps of mass change. Alternatively, ground instruments, regardless of whether they are based on superconducting gravimetry of atom-interferometric accelerometry principles, have a spatially quite limited footprint and would never be able to alleviate these problems.

Upcoming Missions

ESA and NASA have discussed collaboration on satellite gravity missions for more than a decade, both by engaging the community [e.g., the MAss Change and Geosciences International Constellation (MAGIC) Science and Applications Workshop 2023, Pail et al., 2024], and under the ESA/NASA Joint Programme Planning Group dedicated discussions. The two Agencies recently co-signed a Joint Statement of Intent for cooperation on MAGIC (Figure 1). MAGIC is the jointly-developed concept for collaboration on future satellite gravity observations that addresses needs of the international user community and stakeholders, consisting of GRACE-C (NASA and DLR) and the Next-Generation Gravity Mission (NGGM) (ESA) staggered deployment of two satellite pairs. MAGIC will address the interest to join efforts in building a constellation of two complimentary pairs of satellites to deliver novel products of higher temporal and spatial resolution, shorter latency, and higher accuracy, which would lead to new science, applications, and operational services. The constellation is founded on an ESA-NASA joint reference document co-signed October 2020, the MAGIC Mission Requirements Document (Haagmans and Tsaoussi, 2020), which consolidated the needs of the international user community as described in the IUGG 2015 publication (Pail et al., 2015) and the NASA/National Oceanic and Atmospheric Administration (NOAA)/United States Geological Survey (USGS) 2017 Decadal Survey (NASEM, 2017).

The success of MAGIC is enabled by cooperation between NASA and ESA. GRACE-FO will be followed in 2028 by NASA's GRACE-C mission, while ESA's NGGM is foreseen to launch in 2032 in an inclined orbit (Daras, 2023). During the expected overlap period of four years, the two pairs of orbiting gravity satellites in MAGIC will provide new data products with enhanced spatial and temporal coverage and substantially reduced errors due to temporal aliasing, making the data less reliant on de-aliasing models and post-processing. MAGIC will thus provide total water storage anomaly (TWSA) maps at higher spatial resolution and 5-day sampling, requiring less post-processing as compared to GRACE and GRACE-FO. Moreover, MAGIC will deliver products with shorter latency (e.g., fast-track 2-4 days) and higher accuracy (i.e., reduced error), which will enhance assimilation into hydrology models as part of the operational processing. It has already been shown through simulations with realistic background model errors that MAGIC will enable total water storage anomaly retrievals with errors about a factor of ten lower as compared to GRACE-FO. This means that one will be able to resolve smaller and more localized signals, increasing the effective coverage to include more global aquifer and river basin targets, as well as enhanced cryosphere, ocean, and solid Earth monitoring.

A workshop dedicated to MAGIC science and applications was held in Assissi in November 2023 (Pail et al., 2024) to discuss future science potential of the joint mission. To examine the enhanced capabilities of MAGIC, some studies have begun simulating the use of GRACE-C, NGGM, and MAGIC data products within data fusion or data assimilation frameworks. For instance, Kusche et al. (2024) found that assimilation of MAGIC data into global hydrological models would lead errors of 20-year trends at the native grid scale of 50 km to drop to about 1 cm/yr, about what we expect today from GRACE-FO assimilation at 300 km scale, and benefit not only TWSA but also groundwater storage trends. Simulations also suggest that, within sophisticated data fusion schemes, mass change data can constrain precipitation, evapotranspiration, and runoff fluxes and thus aid in the evaluation of model predictions, and also provide the opportunity to estimate water fluxes from MAGIC data (e.g., Camici et al., 2023). For operational applications that focus on water storage extremes, such as floods and droughts, faster temporal revisits will enable assimilation with lower latency data (e.g., Houborg et al., 2012) and allow the examination and analysis of new processes in land surface hydrology for the first time. Examples include the process of drought cascades and the propagation of drought from the surface to depth in soils, along with its effect on the deep rooting systems of plants (e.g., Farhamand et al., 2021), and the formation of the soil saturation conditions that create an antecedent forcing for extreme runoff generation in floods (Reager et al., 2014). The combination of enhanced spatiotemporal resolution, decreased latency, and enhanced accuracy will increase the utility of satellite gravity missions for the water cycle community and enable new levels of scientific achievement for this revolutionary technology.

Future Technologies

Novel methods for measuring Earth's gravitational changes have recently evolved through "quantum gravity" approaches. Quantum sensors are now being used commercially on the ground, and bringing them on onboard spacecraft has been suggested as a means of overcoming the fundamental limitations of space gravimetry. The idea is that future quantum sensors would enable one to refer observed distance variations to ideal free-fall conditions by combining the principles of current gravimetry measurements with cold atom interferometry. This involves using lasers to freeze atoms within the instrument to near absolute zero temperature and then allowing the atoms to move freely in response to the strength of the gravity field. Referring the measured phase difference interferometry as the atoms move in free-fall to the instrument on board the spacecraft enables one to remove non-gravitational accelerations from the laser distance measurement, eventually providing cleaner mass redistribution maps within the Earth's envelope. An obvious challenge is that robust sensor technology must be developed that endures multiple years of mission lifetime. With several studies and laboratory experiments being developed now, we may be still 15 or more years away from seeing a dedicated satellite mission that uses cold atom technology to measure gravity and mass change.

New challenges remain with quantum gravity. For instance, it is very difficult to assess the potential future progress in global tidal and non-tidal ocean and atmosphere models' ability to reproduce mass changes better at timescales of hours and days, and thus aid in "cleaning" the satellite-gravimetric data sets. In this light, it seems preferable to develop future quantum missions as multi-pair constellations (Zingerle et al., 2024), i.e., similar to MAGIC, but with more satellite pairs on multiple orbital planes in order to further increase temporal and spatial resolution. Simulations suggest that such concepts could provide daily or few-day mass change maps for applications in water cycle research with improved accuracy with respect to the anticipated MAGIC concept. While this seems far away, we feel it is imperative for the community to now prepare for the GRACE-C, NGGM, and MAGIC missions, understand the potential of the new data and the specific opportunities created by gravity constellations, and engage early with end-users of mass change data products to both avoid unrealistic expectations but also understand scientific needs. We thus call upon the GEWEX community to revisit potential applications (particularly where GRACE data once seemed too coarse), develop applications for GRACE-C/NGGM/MAGIC, and define new science requirements for the time beyond MAGIC.

References

Camici, S., L. Brocca, C. Massari, A. Tarpanelli, N. Sneeuw, et al., 2024. Potential of NGGM MAGIC for global runoff estimation: the STREAM approach. Presented at MAGIC Science and Applications Workshop 2023, *https://az659834.vo.msecnd.net/eventsairwesteuprod/production-nikal-public/2dff1341162a4ba99cda69eb96b2b02a*.

Daras, I. (ed.), 2023. *Next Generation Gravity Mission (NGGM) Mission Requirements Document*, Issue 1.0, Earth and Mission Science Division, European Space Agency, *https://doi.org/10.5270/ESA.NGGM-MRD.2023-09-v1.0.*

Eicker, A., C. Strohmenger, J. Kusche, C. Braitenberg, and R. Pail, 2024. A survey on user requirements for future satellite gravity missions. Presented at MAGIC Science and Applications Workshop 2023, *https://az659834.vo.msecnd.net/eventsairwesteuprod/production-nikal-public/e705610f7afe4e42820bd0d80a3ca03d*.

Farahmand, A., J.T. Reager, and N. Madani, 2021. Drought cascades in the hydrologic cycle: A set of case studies from remote sensing. *Geophys. Res. Lett.* 48, doi:10.1029/2021GL093482.

Haagmans, R., and L. Tsaoussi, (eds.) 2020. *Next Generation Gravity Mission as a Mass-change And Geosciences International Constellation (MAGIC), Mission Requirements Document*, Earth and Mission Science Division, European Space Agency; NASA Earth Science Division, *https://doi.org/10.5270/esa.nasa.magic-mrd.2020*.

Houborg, R., M. Rodell, B. Li, R. Reichle, and B.F. Zaitchik, 2012. Drought indicators based on model-assimilated Gravity Recovery and Climate. *Water Resour. Res.* 48, W07525 doi:10.1029/2011WR011291.

Kusche, J., C. Strohmenger, H. Gerdener, A. Springer, Y. Ewerdwalbesloh, et al., 2024. Prospects for assimilating data from quantum missions into hydrological and land surface models. Presented at MAGIC Science and Applications Workshop 2023, *https://az659834.vo.msecnd.net/eventsairwesteuprod/production-nikal-public/4d0c3c75ab38435a9cb69b791026b5e1*.

National Academies of Sciences, Engineering, and Medicine (NASEM), 2018. *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space*. Washington, DC, The National Academies Press, *https://doi.org/10.17226/24938*.

Pail, R., R. Bingham, C. Braitenberg, H. Dobslaw, A. Eicker, et al., 2015. *Observing mass transport to understand global change and to benefit society: Science and user needs – An international multi-disciplinary initiative for IUGG*. Deutsche Geodätische Kommission der Bayerischen Akademie der Wissenschaften, Munich, Germany, Verlag der Bayerischen Akademie der Wissenschaften. ISBN 978-3-7696-8599-2.

Pail, R., F. Landerer, A. Eicker, J.T. Reager, C. Braitenberg, J. Sauber-Rosenberg, L. Brocca, M. Rodell, I. Panet, S.-C. Han, S. Bruinsma, and C. Peralta-Ferriz, 2024. *Report of MAGIC Science and Applications Workshop 2023* (Daras, I., L. Tsaoussi, eds.). European Space Agency and National Aeronautics and Space Administration, *https://doi.org/10.5270/MAGIC-Workshop-2023*.

Reager, J.T., B.F. Thomas, and J.S. Famiglietti, 2014. River basin flood potential inferred using GRACE gravity observations at several months lead time. *Nature Geosci.* 7, 588–592, doi:10.1038/ngeo2203.

Zingerle, P., T. Gruber, R. Pail, and I. Daras, 2024. Constellation design and performance of future quantum satellite gravity missions. *Earth Planets Space* 76, 101, doi:10.1186/s40623-024-02034-3.

Water • Climate | 水 • 気候

Call for Submissions to Two Special Issues on the GEWEX Open Science Conference (GEWEX-OSC) in Sapporo

We are pleased to invite you to submit your papers to the special issue of **Hydrological Research Letters** (HRL) and the joint special edition of the **Journal of the Meteorological Society of Japan** (JMSJ) and **Scientific Online Letters on the Atmosphere** (SOLA) dedicated to the outcomes of the 9th GEWEX Open Science Conference (GEWEX-OSC) in Sapporo. All participants of GEWEX-OSC Sapporo have the right to submit manuscripts to any of the journals, and we warmly encourage your submissions.

HRL Submission Details:

Publication Charges: The first 15–20 papers published online by June 2025 in HRL will be exempt from publication fees. Please note that this waiver is limited to the first 15–20 submitted papers due to budget constraints.

How to Submit:

Prepare your manuscript according to the HRL submission guidelines, available at http://www.hrljournal.org/data/hrl_gewex.pdf. Submit your manuscript via the HRL submission portal: https://www.editorialmanager.com/hrl/default.aspx.

When submitting, select "GEWEX-OSC Sapporo" from the drop-down list for Question 7 (regarding special collections). Please include your presentation paper number (e.g., 29–53) and the GEWEX-OSC Sapporo title in the comments section.

For submission assistance, please contact kure@pu-toyama.ac.jp.

JMSJ and SOLA Submission Details:

Submissions related to GEWEX-OSC Sapporo are encouraged to contribute to the "Special Edition on Recent Advances in the Global Energy and Water Cycle Exchanges (GEWEX) Sciences".

How to Submit:

Follow submission guidelines available at https://www.metsoc.jp/jmsj/special_issues_editions/JMSJ2024_GEWEX.html. Manuscripts should be prepared according to the guidelines of either JMSJ or SOLA. The instructions are available for:

- JMSJ: https://www.metsoc.jp/jmsj/instructions.html
- SOLA: https://www.metsoc.jp/sola/instruction.html

Papers must be submitted online via the respective journal's submission system:

- JMSJ: https://mc.manuscriptcentral.com/jmsj (to be renewed in 2025)
- SOLA: https://mc.manuscriptcentral.com/sola

Choose "GEWEX" during the submission process. Please also mention that your submission is for "GEWEX" in the cover letter.

For more information, please refer to the Call for Papers: https://www.metsoc.jp/jmsj/special_issues_editions/CallforPapers_JMSJ-SOLA_SpecialEdition_GEWEX.pdf.

We look forward to your valuable contributions to both special issues.

GEWEX/WCRP Calendar

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

28–30 April 2025—American Water Resources Association (AWRA) 2025 Spring Conference: Development Risks & Challenges in Changing Climate Conditions—Anchorage, AK, USA

14–16 May 2025—Workshop on Global Precipitation Monitoring in a Joint European Effort—Paris, France

19–21 May 2025—GEWEX Upper Tropospheric Clouds and Convection Process Evaluation Study (UTCC PROES)—Paris, France

19–23 May 2025—2025 GEWEX Data and Analysis Panel (GDAP) Annual Meeting—Paris, France

22–23 May 2025—2nd LIAISE Conference—Toulouse, France

26–30 May 2025—Baltic Sea Science Congress 2025—Sopot, Poland

7–10 July 2025—2025 CFMIP-CloudSense Meeting on Circulation, Clouds, and Climate—Exeter, UK

9–11 July 2025—2025 GEWEX Hydroclimatology Panel (GHP) Meeting—Montreal, Canada

14–16 July 2025—International Soil Modelling Consortium (ISMC)–GEWEX Soil and Water Initiative (SoilWat) Meeting—Reading, UK

16–18 July 2025—2025 Global Land-Atmosphere System Study (GLASS)—Reading, UK

27 July–1 August—2025 Asia Oceania Geosciences Society 2025 (AOGS2025)—Singapore

Global Groundwater Network (GGN) Meeting

GGN (*https://www.gewex.org/ggn/*) will have a **Splinter Meeting at EGU** on **Wednesday, April 30th** at 8:30, Room 2.83. Splinter Meeting information can be found at *https://meetingorganizer.copernicus.org/EGU25/session/54888*.

GEWEX QUARTERLY

Published by the International GEWEX Project Office

Peter J. van Oevelen, Director
Shannon Macken, Editor

International GEWEX Project Office
c/o George Mason University
111 Research Hall, Mail Stop 6C5
4400 University Drive
Fairfax, VA 22030 USA

E-mail: contact@gewex.org
Website: *http://www.gewex.org*