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Executive Summary

This report documents the proceedings of the 36th Session of the Global Energy and Water Exchanges (GEWEX) Scientific Steering Group (SSG), the annual meeting of scientists who guide the formation of GEWEX's scientific program as well as Chairs and Co-Chairs of the GEWEX Panels. This year's annual meeting has taken place at the HungaroMet Nonprofit Zrt., Budapest, Hungary, from Monday to Friday, 22–26 April 2024.

During this session, attendees reviewed the progress made by GEWEX and its four Panels throughout 2023, assessing the program's relevance to current and future global challenges. Each of the four Panels reported on a range of activities undertaken in 2023, which included the onboarding of new Panel members, the initiation of new projects, the development and marketing of various scientific products, and the organization of both virtual and in-person workshops. The reports indicated that ongoing projects are progressing as planned, while some have concluded successfully. Moreover, working groups across the Panels have made significant contributions to the scientific community, publishing articles in leading journals, with additional manuscripts currently under review. Discussions on how to proceed, what is lacking, other possible topics to explore and discussions on existing or possible obstacles resulted in new action items and recommendations.

This year's meeting also saw the first selection of nominees for the GEWEX Lifetime Achievement Awards. This award has been created to honor colleagues who, over the span of their career, have contributed in a substantial way to GEWEX and will only be presented during a GEWEX Open Science Conference (OSC).

A significant focus of the SSG meeting was the detailed planning for the 9th GEWEX OSC, scheduled to be held at the Keio Plaza Hotel in Sapporo, Japan, from 7–12 July 2024. This conference is being organized in collaboration with Hokkaido University and the Science Council of Japan, emphasizing the importance of international cooperation in addressing global water and energy challenges.

Contributions from GEWEX partners and WCRP core projects and activities completed the program of this year's SSG meeting.

In 2023, the support required to meet the obligations and responsibilities of the International GEWEX Project Office (IGPO) was provided by George Mason University under the Center for Ocean-Land-Atmosphere Studies (COLA).

In Phase IV (2023–2032) of GEWEX, the GEWEX Science Plan 2023–2032, *Addressing the challenges in understanding and predicting Changes to water availability in the coming decades*, was published (WCRP publication no. 9/2021). It serves as the backbone of, and provides direction to, the GEWEX strategic plan and science questions for the coming years.

Contents

1. Introduction

This report summarizes the main developments in GEWEX in 2023 and includes the major items and recommendations from the 36th Session of the GEWEX Scientific Steering Group (SSG-36).

The GEWEX SSG-36, hosted HungaroMet Nonprofit Zrt., took place in Budapest, Hungary, from Monday to Friday, 22–26 April 2024. The focus of this meeting was on:

- developments of the GEWEX Panels over the past period and goals for the coming year
- discussions about the new GEWEX Science Plan and other strategy documents related to Phase IV (2023–2032) of GEWEX
- developments and collaboration with the sister Core Projects and Lighthouse Activities (LHAs) of the World Climate Research Programme (WCRP)
- preparation and organization of the GEWEX Open Science Conference jointly organized with Hokkaido University and the Science Council of Japan, which will take place in July 2024 in Sapporo, Japan
- collaboration with GEWEX partners, and
- a special section of the SSG-36 was reserved for presentations and discussions with members of the Pannonian Basin Experiment (PannEX), a GEWEX Hydroclimatology Panel (GHP) Network of scientists focusing on the Pannonian Basin.

An overview of the points of discussion and attention raised during Panel presentations are mentioned in §1.1. Major results, goals and plans of each of the GEWEX Panels are shown in the individual annual Panel reports in §2. The annual report of each Panel is based on the annual reports of the individual working groups and projects within that specific Panel. Each Panel was assigned two or three SSG members as rapporteurs. The rapporteurs reported on the development, progress and challenges faced by the assigned Panel together with recommendations for improvement or follow-up. Their findings are described in the rapporteurs' report placed after each assigned annual Panel report in §2.

The development, plans and possible and/or existing areas for cooperation with GEWEX of participating representatives from the World Meteorological Organization (WMO) and WCRP groups, and other GEWEX partners and sponsors, are summarized in §1.2 and § 1.3 respectively.

The complete list of participants of the GEWEX SSG-36 can be found in Annex 1 and the agenda of the SSG-36 in Annex 2.

1.1. GEWEX and GEWEX Panels

The GEWEX mission, in short, is the "quantitative understanding and prediction of the coupling of energy and water in the changing Earth system." The GEWEX SSG shapes and monitors the course of GEWEX and briefs WCRP's JSC. The GEWEX SSG consists of two Co-Chairs and 11 panel members, two GEWEX Ambassadors and ex-officio members from National Aeronautics and Space Administration (NASA), European Space Agency (ESA), Japanese Aerospace Exploration Agency (JAXA) and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). There are three major areas of research within GEWEX: i) Data and Analysis, ii) Hydroclimatology and iii) Modeling and Prediction.

GEWEX is made up of four Panels, each consisting of several working groups, which explore the above-mentioned major research areas. In addition, the CLIVAR/GEWEX Monsoon Panel is a joint activity with WCRP's core program Climate and Ocean: Variability, Predictability and Change, Predictability (CLIVAR). GEWEX representatives also participate in the six WCRP Lighthouse Activities (LHAs).

A "Science and Applications Traceability Matrix" (SATM) was assembled with input from all SSG and Panel members and served as the backbone of, and provided direction to, the GEWEX Science Plan 2023–2032 - Phase IV 2023–2032 (Fig. 1) and the GEWEX science goals and imperatives for the coming years. The third phase of GEWEX (2013–2022) concluded with an article in the *Bulletin of the American Meteorological Society* (BAMS) entitled "The First 30 Years of GEWEX", https://doi.org/10.1175/BAMS-D-22-0061.1.

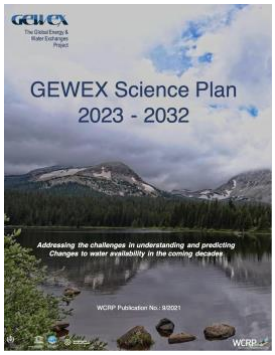

Fig. 1 GEWEX Science Plan 2023–2032

The International GEWEX Project Office (IGPO) facilitated and coordinated GEWEX research across GEWEX studies, activities and products. IGPO oversaw the implementation of the recommendations given by the GEWEX SSG and played a central role in the outreach of GEWEX through its websites, quarterly newsletter, monthly E-News, social media and direct support to GEWEX and GEWEX-related initiatives, science conferences and workshops. IGPO also provided an interface between GEWEX and other WCRP activities, as well as other global environmental science and space science programs.

In 2023, George Mason University, under the Center for Ocean-Land-Atmosphere Studies (COLA), provided the support required to meet the obligations and responsibilities of the IGPO and its Director directly or indirectly through access to the necessary facilities and staffing.

The GEWEX Panels are the:

1. **Global Atmospheric System Studies** (GASS) Panel, which aims to improve the understanding of physical processes in the atmosphere and their coupling to atmospheric dynamics. GASS Panel activities facilitate and support the international community that carries out and uses observations, process studies and numerical model experiments that contribute to the physical understanding of atmospheric processes and their representation in weather and climate models.

   The GASS annual report is shown in §2.1 and the GASS rapporteurs' report in §2.1.1.

2. **GEWEX Data and Analysis Panel** (GDAP) is organized to bring together theoretical and experimental insights into the radiative interactions and climate feedbacks associated with

3. cloud processes. The central question that governs the GDAP mission is: "*how sensitive is the Earth's climate to changes in radiative and other forcings?"* GDAP is climate-oriented, consistency-driven and focused globally and worldwide, where observations are centric to its activities.

   The GDAP annual report is shown in §2.2 and the GDAP rapporteurs' report in §2.2.1.

4. **GEWEX Hydroclimatology Panel** (GHP) concentrates on improving our understanding of environmental water and energy exchanges at the regional scale and from an integrated perspective. Addressing the water cycle at the regional scale allows us to better understand the many components of the system, from its physical to economic to social aspects. The GHP projects and working groups are organized in four categories:

   a) Regional Hydroclimate Projects (RHPs), an essential tool in understanding and predicting hydroclimates as they bring together various disciplines on water-related issues.

   b) Crosscutting Projects (CCs) allow GHP to propagate knowledge from one region to another and synthesize results at the global scale. CCs also facilitate the development and testing of applications derived from this new understanding.

   c) Global Data Centers collect and distribute important hydrology-related data.

   d) GHP Networks maintain collaboration and capacity building activities relevant to GEWEX science.

   The GHP annual report is shown in §2.3 and the GHP rapporteurs' report in §2.3.1.

5. **Global Land/Atmosphere System Study** (GLASS) Panel, whose objective is to improve i) the understanding of energy and water cycling on land and in the coupled land-atmosphere system and ii) representation of these processes in Earth system models. GLASS projects also address interactions between the land and the atmosphere, with scales of interest ranging from observational site-scale process understanding applicable to sub-diurnal to seasonal timescales, out to continental and global climatological understanding of the interconnected water, energy, and carbon cycles. The GLASS Panel encourages these developments by coordinating the evaluation and intercomparison of the new generation of land models and their applications to scientific queries of broad interest.

   The GLASS annual report is shown in §2.4 and the GHP rapporteurs' report in §2.4.1.

6. **CLIVAR/GEWEX Monsoon Panel** (MP) membership is derived from i) the CLIVAR community, whose research into ocean-atmosphere interaction and the role of slowly varying modes lends predictability to the monsoons, and ii) GEWEX community activities in land-atmosphere interaction and convective scale processes, which are key to understanding monsoons from regional to global scales. The Regional Monsoon Working Groups, comprising the Asia-Australia, Americas and Africa regions explore a more global view of monsoon activities with emphasis on the role of convection and land surface in the monsoons, in addition to ocean-atmosphere interaction. It attempts to better coordinate monsoons research between GEWEX and CLIVAR, enabling knowledge and best practices to be shared between the various monsoon regions.

   The MP annual report is shown in §2.5 and the GHP rapporteurs' report in §2.5.1.

GEWEX is a volunteer-driven organization that carries out activities that initiate from and resonate within the community. A wide variety of research communities build upon GEWEX science.

The GEWEX Panels play a pivotal role in i) directing activities towards addressing the goals and imperatives outlined in the decadal GEWEX Science Plan based on the WCRP agenda, ii) facilitating interactions among individuals and groups interested in initiating projects and iii) connecting many different research communities. As GEWEX projects relate to topics that are connected, (inter-)Panel discussions also stimulate collaboration and lead to cross-cutting activities. Additionally, membership in the international GEWEX/WCRP community provides significant advantages when seeking funding from the various agencies.
Financial support for GEWEX activities is available in the form of a limited budget for travel support, aimed at early career scientists and researchers from developing nations, enhancing their ability to participate in these events.

Points of discussion and attention raised during Panel presentations are:

- At the start of a new project, ask the working group how it can contribute, collaborate and/or what it needs from existing projects within the Panel and also how it can link to projects in the other GEWEX Panels. Ask the existing projects these same questions about the new project.
- GASS is advised to connect with the regional climate modeling community.
- Look at activities that are already in place as starting points for further inter-Panel collaborations, e.g., the irrigation project for GLASS and GHP.
- Look ahead and inform the international GEWEX project office about event planning well in advance, especially when financial support is requested.
- The upcoming GEWEX Open Science Conference (OSC) might be a good venue to look for potential new Panel members and/or activity leads with specific expertise.
- Research highlights and lessons learned through GEWEX activities should be made public and capitalized on in a consistent manner. Another suggestion in this context is to build processes that have pipelines to places where data and ongoing scientific efforts can be easily updated, rather than writing papers only.

In addition to the presentation of the GEWEX Panels, a status overview was given on the upcoming 9th GEWEX OSC in Sapporo, Japan from 7 to 12 July 2024. A timeslot was reserved for discussion about the current composition of the SSG and the necessary changes due to ending terms for a couple of members. This timeslot was also used to discuss the nominations for the Lifetime Achievement Award and GEWEX ambassadorship, which will both be presented at the GEWEX OSC.

The following challenges and points of attention were mentioned during the strategy discussion:

- the number of active projects is growing; however, funds to support these activities are declining. Quality should prevail over quantity
- in addition to liaisons, a different tactic to link the various GEWEX projects would be to use a bottom-up approach through the projects themselves
- ways to connect back to agencies and figuring out how GEWEX activities can determine their current and future direction and communicate their needs
- records of data usage would be useful to space agencies to inform them of what data is useful and needed
- keep in mind why GEWEX exists: GEWEX activities build bridges between all modeling activities and societal impacts both in terms of observations and understanding of models and their limitations

- it may be important for GEWEX to bring together the weather and climate communities as they tend to focus on different aspects
- ensure that proposals for collaboration with other groups in WCRP discussed in an SSG meetings are initiated and followed up
- connect crosscutting activities also across Panels
- communicate directly with Panel members to give more context to ideas derived in an SSG meeting
- how can GEWEX maintain its relevance and trademark of doing basic science that directly or indirectly benefits society with all the new and upcoming activities in WCRP that overlap with GEWEX's area of expertise?
- create a forum where the WCRP Core Project (CP)'s co-chairs and project office directors get together. This might improve the interaction and collaboration between CPs and CPs with the WCRP JSC
- is the *GEWEX Quarterly* the best use of an author's time (how many people read it and how much impact do these articles have)? Should the distribution of the *GEWEX Quarterly* be expanded to include not only the GEWEX community, but also the funding agencies?
- stimulate participation of early career scientist in projects, Panels and the SSG
- stimulate more cutting-edge science and/or usage of satellite data simulator and contribute to intellectual improvement of the development of our understanding of processes
- WCRP has a complex, fragmented and hierarchical structure. Researchers at the bottom of the pyramid who do the actual science feel the most pressure, especially if a project is successful or shows promise. These projects are approached by many entities from the WCRP group, which can compromise the identity of the project and puts a lot of pressure on its project members
- increase attention on monsoons
- create guidelines for, or assist, new project leaders on how to connect and get more involved in GEWEX and let them know what is expected from them
- improve communication within and between Panels, and with the outside world to inform them what is happening in GEWEX. The GEWEX website could play an important and useful role in this, as could regular conference calls with Panel co-chairs and SSG members.

Our host HungaroMet, established in 1870 by Franz Joseph I, gave several presentations, which included an overview of its history and ongoing research. Every meteorological measurement in the country, including data from citizens' platforms, are recorded in Hungary's national observational database. Hungary follows an open data policy. A part of the data is available via EumetNet. The European Centre for Medium-range Weather Forecasts (ECMWF) systems are used for seasonal weather prediction and social media to inform the public about climate change.

The future and greatest challenge of the GHP Network PannEX, a network for the Pannonian basin, depends largely on how collaboration between the different countries involved in this area can be enhanced. The PannEX presentation informed us on the work and progress addressing the key questions and focus areas (Fig. 2). Currently and despite its importance, issues regarding water quality are of little interest to the members of the PannEX community. The data that PannEX contributed to GHP's Global Precipitation Climatology Centre (GPCC) Data Center is not yet visible. This matter will be taken up at the GEWEX Open Science Conference in Sapporo, Japan.

PannEX is asked to write a short article for the *GEWEX Quarterly* about how WCRP and GEWEX in particular contributed to the science in the Pannonian region.

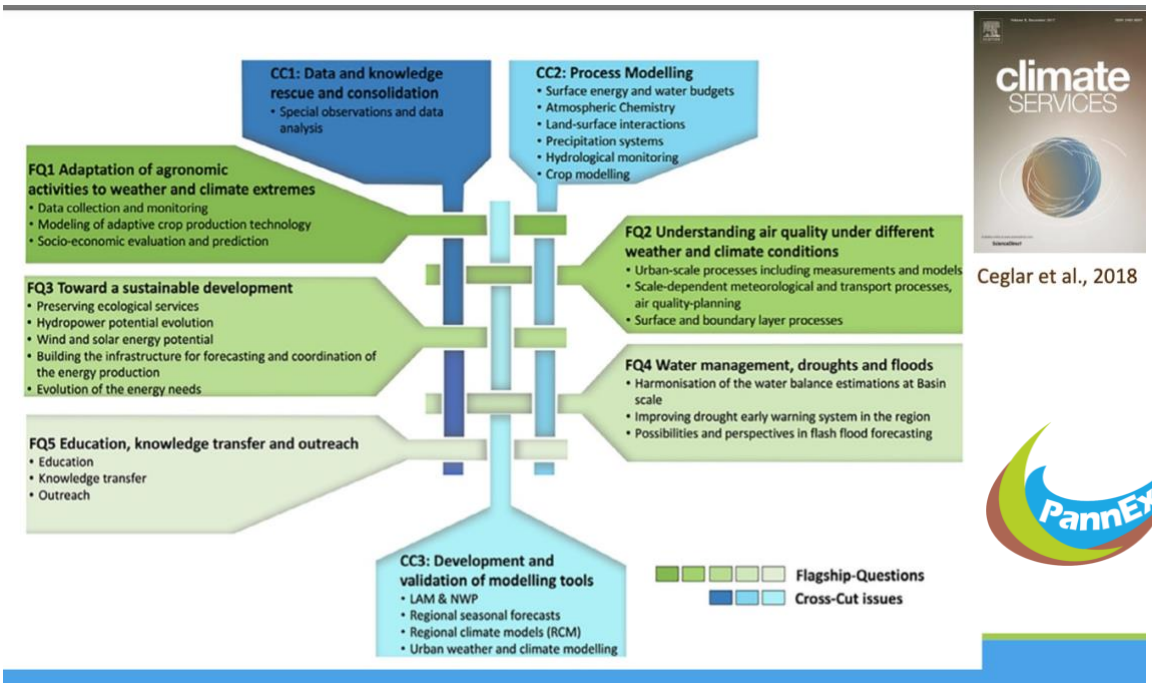

Fig. 2 PannEX key questions and focus areas

1.2. GEWEX Links to WMO, WCRP and WCRP Core Projects

At the SSG-36, several members of WMO and WCRP groups were represented and gave an overview of their current and future activities and possible areas of collaboration with GEWEX. From the WCRP group, several WCRP core projects participated, namely Climate and Cryosphere (CLIC), CLIVAR, the Coordinated Regional Climate Downscaling Experiment (CORDEX)[1], Earth System Modelling and Observations (ESMO) and Regional information for Society (RIfS)[1]. The Global Precipitation Experiment (GPEX), a WCRP Lighthouse Activity, and WCRP's Joint Scientific Committee (JSC) and secretariat also joined. The WMO Hydrology and World Weather Research Programme (WWRP) participated from WMO. Points of discussion, possible areas of collaboration and other relevant details are mentioned below.

With the sunsetting of WCRP's Grand Challenges (GCs) and the beginning of its Lighthouse Activities (LHAs), WCRP has increased the gap between its activities and societal requirements by removing the emphasis on what society is interested in, e.g., floods and water resources. Although some members of GC working groups and projects are active in LHAs, and WCRP has suggested that the new LHAs carry on with activities from GCs that were not finished or objectives not achieved, it is primarily the interest of the experts in the LHA that determine what topics are worked on. With respect to the two GCs GEWEX was leading, *Water for the Food Baskets of the World* and *Understanding and Predicting Weather and Climate Extremes*, the current LHA committees are dominated by abstract modelers and oceanographers whose interests do not match what society wants, e.g., precipitation versus floods and rainfall.

[1] Pre-recorded presentation only.

One suggestion is to bring the social focus back into the LHAs. In the long term, this could lead to the working groups realizing what information is needed and asked for. A second suggestion is to put more effort in the connection with the WCRP Core Projects (CPs).

WCRP has announced a call for a research fellowship with a focus on Africa. The duration of the fellowship can be 1 year or as long as the provided resources of 50k CHF last to support the candidate full time. This initial starting point of a WCRP fellowship is to draw the attention and interest of agencies and to attract additional funding. During the meeting, questions were raised if WCRP is the appropriate organization to organize and fund such a fellowship and if the current conditions of the fellowship will meet the requirements for training of the next generation of leader(s) in climate change research. WCRP could support and/or recognize already existing programs, for example. Discussion ensued on more effective and efficient ways to spend the available budget, such as starting an RHP in Africa instead of making the WCRP Core Projects (CPs) compete with each other and with third parties.

WCRP's JSC liaisons form the bridge between the WCRP Secretariat and JSC on the one hand and the CPs on the other. They work with the CP's co-chairs and project office director on the CP's programmatic needs and its Scientific Steering Group membership. During the meeting, they will inform the JSC members about progress, gaps and needs of the CP. Although the JSC should support, facilitate and guide the CPs, GEWEX experiences an unproductive top-down style of communication in the collaboration. For example, regarding the new financial support model that will be used to determine the CPs' WCRP budget in 2025, it was implemented immediately without prior consultation with the CPs' leadership. Over the years, GEWEX has raised many issues with the JSC in various ways that have not resulted in a response or improvement in ways of communication, interaction and collaboration.

"Cycles and budgets" is a joint effort by WCRP and the Global Climate Observing System (GCOS) trying to establish the state-of-the-art in closing the cycles for the conservative quantities in the Earth system. It is important fundamental research looking at all potential elements involved in cycles and fluxes. This effort aims to provide a framework that will link all relevant essential climate variables, guaranteeing these are defined consistently and are observable, and will quantify the uncertainties.

The Global Precipitation Experiment (GPEX) is a new WCRP LHA focusing on accelerating the improvement of precipitation prediction and projection skills. The group is currently installing the permanent members of the scientific steering committee. For detailed information, visit https://www.wcrp-climate.org/lighthouse-activities/gpex/GPEX-SciencePlan-Nov2023.pdf.

CLiC galvanizes international activities that are looking at the frozen parts of the planetary realm and coordinates existing and new activities that address key challenges in this area. Its recently published new strategic plan includes basic research and affected societal impacts in the ecosystem. Last year, CLiC's project office moved from the University of Bergen to the University of Massachusetts and was able to increase its staff to 2.5 full-time units.
CLiC plans to celebrate its 30-year anniversary by organizing an open science conference in 2026. Input and lesson learned from the GEWEX Open Science Conference in Sapporo, Japan will be appreciated.

CLiC's newest proposal is Impacts of Changes in the Mountain Cryosphere (IC-MontC), an activity that will focus on the mountainous cryosphere. This could be an opportunity for CLiC and GEWEX to collaborate in terms of the energy and water cycles and could be used to revitalize the Snow Models Intercomparison Project (SnowMIP), a former collaboration between

CLiC and GEWEX. It was also suggested that IC-MontC could be a suitable occasion to bring the mountain or glacial park and other land surface communities together. It was noted, though, that there seems considerable overlap with GEWEX activities such as INARCH while the entire community is rather small.

A possible cross-cutting activity put forward during the CLiC presentation involved building consistent retrievals to obtain snow and ice properties together with water vapor, clouds and snowfall in a consistent manner.

CLIVAR is mainly focused on big ocean basins and ocean-atmosphere coupling in the context of climate variability and change. There are no high-resolution ocean modeling efforts currently, nor is there focus on coastal processes, including hazards such as storm surges. Within the framework of WCRP's Earth System Modelling and Observations (ESMO), there are plans towards coordinated regional ocean modeling jointly with WCRP's Coordinated Regional Climate Downscaling Experiment (CORDEX). The CLIVAR community is also interested in simulating freshwater fluxes and incorporating increasingly sophisticated river routing schemes in ocean modeling.

There is hardly any focus on coastal modeling in terms of operational short-range forecasting within WMO/WCRP, even though it concerns matters of life and death. This offers opportunities and a societal need for collaboration between the CLIVAR and GEWEX communities. There is a big area of research where the expertise of both can be combined, such as:

- costal and tidal zones where interface and dynamics change
- storm surge inundation
- coupling of land-atmosphere interaction and ocean-atmosphere interaction systems
- sea breezes and circulation
- atmospheric bridges: variability over land, such as soil moisture or temperature can induce and influence the ocean via the atmosphere and vice versa.

CORDEX is a global collaboration on regional downscaling and regional climate information. It currently celebrates its 15th year of operation. CORDEX works with regional and local climate phenomena and their variability, trying to produce coordinated easy-to-use climate information for regions. An area of possible collaboration with GEWEX is on global coordination of convection permitting activities.

The ESMO Core Project was approved by the WCRP JSC in November 2020 with the mandate to structure, coordinate, advance and facilitate all modeling, data assimilation and observational activities within the many working groups across WMO, WCRP and core projects. Looking at models and observations as a whole is currently not happening in WCRP. Also, the many groups dealing with observations are not well connected to the bigger modeling groups.

One suggestion is that ESMO can assist with the distribution and deployment of GDAP's systematic dataset assessments across the WCRP group and further optimize this tool, for instance, on usage of observations and models. Furthermore, ESMO and GEWEX should initiate a discussion on the task of carbon monitoring to determine "who does what" and what is the purpose of each activity. On a large range of variables, the goal would be to build guidance on data usage. Currently, the choice of which observation data to use is determined by what is known to the user and/or colleagues and not by the strengths or weaknesses of the data.

A lot of modeling activities have moved to link to societal needs and impacts. The bridge between modeling and those societal needs and impacts is what is happening over land, which is addressed by several GHP and GLASS activities. Another opportunity for ESMO is to raise and reinforce the importance and significance of the land part in models.

To improve operationality, the observational need for modeling is to obtain the historical forcings that are used as input data into Global Climate Models. The historical forcings from the 6th Climate Model Intercomparison Project (CMIP6) that are now running are outdated, as it stopped in 2014. It is therefore of acute importance to find organizations that will invest in keeping selective datasets ongoing and up to date. The planned ESMO global survey on observational needs will require support from GEWEX.

If resources are available, horizon scanning and network analysis of activities within the different WMO/WCRP groups could be a role for the WCRP Secretariat and the JSC to make its activities more effective and efficient with less overlap and unnecessary duplication.

In hindsight, the WCRP JSC should have obtained input from the Core Projects before installing the ESMO structure to limit and prevent unuseful overlap.

RIfS is intended to help advance international collaboration and consensus on bridging the gap between climate research and climate information used in decision making. RIfS is also the umbrella entity for CORDEX and the developing Global Extremes Platform (GEP). GEP builds upon and integrates activities on weather and climate extremes across WCRP. It is designed to contribute to improving the ways of delivering science, information and data concerning extremes in a well-synthesized format for the climate research community, policymakers and other users of climate science.

Currently, RIfS has started working with GEWEX's RHP ANDEX on a joint session at the ANDEX annual meeting in Peru in May. Another possible area of collaboration between CORDEX/RIfS and GEWEX is to organize an RHP in Africa.

The presentation of WMO Hydrology focused on user perspective and on collaboration with partners in the research community. Recently, a new task team called Hydrology Research of the WMO Research Board was installed, which include two members of GEWEX. Their first points of action include the reviews of the WMO Plan of Action for Hydrology and WMO Hydrological Research Strategy (2022–2030). 2025 has been declared the International Year of Glaciers' Preservation. GEWEX, among others, is asked to nominate members for the advisory committee.

Rivier discharge is a specific area where collaboration with GEWEX can be intensified through development of better parameters and assessments and to analyze the hydrological situation on data. GHP's Global Runoff Data Center (GRDC) is already assisting with getting more data in time to these assessments. Informative precipitation maps for operational water managers, which assess the precipitation situation in a given year, are not yet available and could be developed in collaboration with the GEWEX community.

WMO Hydrology applies the unified data policy, i.e., for sharing data with other parties. In some countries, however, hydrological data is still treated as a national secret because it is a resource that enables economic development. Those countries are hesitant to share data. Therefore, it is also up to the scientific community to work together to make hydrological data accessible for everyone.

The WMO World Weather Research Programme (WWRP) promotes international and interdisciplinary research for more accurate and reliable forecasts from minutes to seasons, expanding the frontiers of weather science to enhance society's resilience to high-impact weather and the value of weather information for users. WWRP aims at seamless prediction by increasing convergence between weather, climate and environmental approaches. One of the hurdles to overcome to reach seamless prediction is the division and jurisdiction of responsibilities across multiple levels, e.g., the atmosphere falls under federal jurisdiction, while hydrology falls under regional jurisdiction. This divided jurisdiction gets in the way of a smooth flow of information to the appropriate parties. The way forward is to build bridges between the different entities and demonstrate the benefit of integrated hydrology in weather models.

WWRP's Urban Prediction Project (2025) project aims at developing applications and evaluating sub-kilometer modeling techniques for vulnerable communities and advancing the concept of digital cities. This project would benefit from connecting to both GASS and GLASS, as the atmospheric part of high-resolution modeling is not done in the urban community and is also not sufficiently connected to the atmospheric modeling community. GEWEX should make the integration of urban and outside schemes in models one of its research priorities.

1.3. GEWEX Interactions with Sponsors and Partners

At the SSG-36 the following sponsors and partners were represented and participated: Centre National D'Études Spatiales (CNES), Copernicus Programme, European Centre for Medium-range Weather Forecasts (ECMWF), European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA). Each representative gave an overview of present and future activities related to GEWEX activities and in-depth information some of its projects relevant to GEWEX.

Less than 1% of the water levels in the millions of freshwater lakes are monitored, either because they are unmonitored or are regarded as state secrets. The Hydrology platform called Hydoweb.next is one of the thematic platforms in CNES's Data Terra, an infrastructure for in situ and satellite data. It contains Surface Water and Ocean Topography (SWOT) products, in situ measurements and products from previous satellite missions. With this data, researchers can compare derived time-series, and it also offers a virtual environment to process data.

Understanding and predicting global energy and water exchanges are more important than ever in an increasingly weather-sensitive society and a changing climate.
ECMWF's primary mission is to carry out medium range, numerical weather predictions and monitoring of the Earth system. Destination Earth (DestinE), a digital twin, is looking at different models. It includes not only atmospheric models, but also river flow, hydrology and socio impact sectors like pollution, biodiversity, food and agriculture. They are developing their own machine learning model (AI MI) that is competitive with large scale companies like Huawei and Google. The link to GEWEX is the interest in hydrology and the land surface.
There are still a lot of questions and uncertainties. Trying to improve these models is key.
ECMWF's Integrated Forecasting System (IFS) is already contributing to GASS's DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains (DYAMOND)

project. In the past, ECMWF has also collaborated on other GASS projects like *Demistify* and is looking into others.
ESA's efforts are aimed at collaboration, to build and benefit from each other's strengths. Community feedback is used to set priorities, determine gaps and strategies and decide how to use the data when preparing for new programs or activities. The Copernicus Data Space Ecosystem gives access to a wide range of data and services from the Copernicus Sentinel missions, including data processing. ESA will continue its support and collaboration with GEWEX.

EUMETSAT is an operational agency and offers continuity and commitment to provide stable data records by using overlapping sensors. It does not directly fund any third-party research. There are, however, opportunities using their infrastructure. The Climate Monitoring Satellite Application Facility (CMSAF), created to produce climate data records, has produced a new precipitation data record that has participated in all GDAP assessments. The GDAP originated next-generation International Satellite Cloud Climatology Project (ISCCP-NG) has used Geostationary Ring output for its modern instruments as it is more interested in processes and concentrating on cloud products. Currently, ISCCP-NG receives base funding from EUMETSAT and NOAA to produce the underlying radiance records.

In collaboration with ECMWF, the European Weather Cloud has set up a distributing Cloud Infrastructure to serve the European meteorological infrastructure and its users. Fractions of the Cloud's machinery can be used for research activities with non-member state partners like GEWEX. Every spring (late March/early April), it puts out a research and development call which is aligned with ECMWF's special projects call.

GEWEX wants to run land-surface models near real-time to do an assessment of the carbon or water cycle. In collaboration with EUMETSAT and ECMWF, correction of the reanalysis in near real-time can force all land surface models and an assessment can be made of unobservable variables. Data is already available, and it would be easy to progress to a use-case using the infrastructure. Further discussion is needed between GEWEX, EUMETSAT and ECMWF on how to run the computer system linked to the data lake.

JAXA's contribution to the energy and water cycle research includes monitoring of precipitation, land and sea surface temperature, aerosols, etc. and engagement with the model development community to improve climate projections and weather forecasting. The challenges JAXA faces currently are to maximize utilization of satellite data and the need for physically consistent data for understanding climate processes to meet society's requirements. JAXA will continue its support and collaboration with GEWEX.

The work at NASA Earth Science Division is directed by a solicited report called the Decadal Survey from the US National Academy of Sciences. This survey lays out the priority observables, which NASA then groups into five missions. Unique to NASA is the commercial acquisition program, which gives U.S.-based scientists the opportunity to request commercial satellite data. NASA will prioritize investments, but once the data is purchased, it will become publicly available.

NASA is seeking to intensify collaboration with the GEWEX community. GDAP is asked to assist with writing the solicitation for NASA's Energy and Water Cycle Program on the integration of multi-agency satellite-based products for closing the global water-carbon-energy budget. GLASS and GASS are asked to lead and/or contribute to a community white paper to define what NASA's water and energy cycle research investment priorities should be. This document can be incorporated in the next Decadal Survey, which will ensure there is already a consensus document on the goals and priorities related to the water and energy cycle as identified by the GEWEX community. GHP is asked to partner in the Earth Action initiatives and

respond to the research opportunities to identify and help implement those new programs. GEWEX is advised to think big and look towards long-lead, coordinated planning for multi-agency, multi-national projects.

- NOAA's role is to engage and facilitate collaboration between its research community and external communities aiming to entrain and complement external expertise and build on the research that is ongoing in NOAA. Of particular interest to the GEWEX community is NOAA's Climate Program Office (CPO) Earth System Science and Modeling (ESSM) Division, which starts an annual solicitation around July and which is open to U.S. and Non-U.S. participants. Applications need to advance NOAA's mission and be relevant to the call.
-
- The strategic goal of the Precipitation Prediction Grand Challenge (PPGC) is to provide more accurate, reliable and timely precipitation forecasts across timescales from weather to subseasonal-to-seasonal (S2S) to seasonal-to-decadal (S2D) through the development and application of a fully-coupled Earth system prediction model. GEWEX research and data can be fed into PPGC and disseminate GGGC input back into the international community.
- NOAA's Climate Process Teams (CPTs) play an important role in process understanding. Ongoing GEWEX projects in this area can be of help in selecting topics for future calls for proposals.

2. GEWEX Panel Status Reports

2.1. Global Atmospheric System Studies Panel (GASS)

Full Panel Name (Acronym) : Global Atmospheric System Studies Panel (GASS)
Reporting Period : 01 January - 31 December 2023
Starting Date : 2018
End Date (where appropriate) : NA
URL : www.gewex.org/panels/global-atmospheric-system-studies-panel

Membership

Chair(s) and Term Dates : Daniel Klocke, 2017 – Present
Sandrine Bony, 2021 – Present

Members and Term Dates : Ian Boutle, 2018 – 2024
Ann Fridlind, 2021 – Present
Carla Gulizia, 2020 – Present
Louise Nuijens, 2023 – Present
Felix Pithan, 2023 – Present
Martin S. Singh, 2019 – Present
Philip Stier, 2023 – Present
Claudia Stubenrauch, 2022 – Present
Shaocheng Xie, 2018 – Present
Yongkang Xue, 2018 – Present

Panel Objectives, Goals and Accomplishments during Reporting Period

Overall Panel Objective(s)

The Global Atmospheric System Studies (GASS) Panel activities facilitate and support the international community that carries out and uses observations, process studies and numerical model experiments with the goal of advancing the understanding and prediction of weather and climate. Primarily, GASS coordinates scientific projects that bring together experts to contribute to the physical understanding of atmospheric processes and their representation in weather and climate models.

List of Panel Goals
Adjust yearly

- Sharpen the scientific goals and ongoing projects of GASS, especially the 'newest' GASS projects
- Maintain and develop collaboration with other GEWEX panels and WCRP communities (e.g.the Working Group on Numerical Experimentation (WGNE), Cloud Feedback Model Intercomparison Project (CFMIP), Lighthouse Activities]
- Facilitate communication and cross-fertilization across the 10 GASS projects
- Organize the GASS-CFMIP conference (Paris, July 2023)
- Update Panel composition according to pan-GASS outcome and new projects

List of 2 to 3 Key Results
Adjust yearly with respect to goals

Successful CFMIP-GASS conference in Paris (9-13 July 2023, hosted by the Laboratoire de Météorologie Dynamique (LMD)/Sorbonne University, with 220 participants, 10 working groups, an early career awards competition for the best presentations and for the best posters (6 prizes awarded).
Discussion and sharpening of several GASS projects at the CFMIP-GASS conference, and discussion of new topics of CFMIP-GASS collaborations (e.g., cloud feedbacks associated with cold-air outbreaks or mesoscale organization)
Finalization of the simulation and intercomparison protocols of several GASS projects: EUREC4A-MIP, DYAMOND3, Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE), Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC)

Other Science Highlights
Not part of the 2-3 key results

- Impact of Initialized Land Temperature and Snowpack on Sub-Seasonal to Seasonal Prediction Phase II (LS4PII): Reveals for the first time that high-mountain land temperature could be a substantial source of S2S precipitation predictability, with an effect probably as large as ocean surface temperature over several “hotspot” regions; publication of overview papers
- Improving the Simulation of Diurnal and Sub-Diurnal Precipitation over Different Climate Regimes (DCP): Overview paper published on the results of Phase I on the diurnal cycle and intensity distribution of precipitation in General Circulation Models (GCMs) used in free mode and/or in hindcasts; evidence for biases in the frequency of light-to-moderate rain, and in the diurnal phase of precipitation over land; preparation of Phase II
- The GEWEX Aerosol Precipitation initiative (GAP): Overview paper published; Radiative Convective Equilibrium Model Intercomparison Project (RCEMIP) aerosol experiments run; plans for global storm-resolving model (GSRM) experiments with aerosols
- GEWEX Upper Tropospheric Clouds and Convection Process Evaluation Study (UTCC-PROES): release of the Clouds from IR Sounders- Machine Learning (CIRS-ML) dataset of cloud vertical structure and radiative heating rates; assessment of convective organization indices published; workshop on convective tracking algorithms (April 2023, Oxford)
- EUREC4A-MIP: simulation protocols for present-day and pseudo global warming simulations ready; cloud botany ensemble of large-eddy simulation (LES) simulations released
- Cumulus friction: evidence for the impact of momentum transport by shallow convection on the strength and structure of the Inter-Tropical Convergence Zone
- Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE): Model-Observation Intercomparison Project (MIP) protocol and tools ready; first LES simulations done –
- MOSAiC: Paper published on the MIP protocol
- Deep organization: Workshop on convective tracking algorithms
- DYAMOND: Phase III protocol of GSRM intercomparison ready

Panel Activities during Reporting Period

List of Panel Activities and Main Result

Quasi-regular meetings of the GASS Panel in teleconference and Panel meeting in person (with all but one member) in Paris during the CFMIP-GASS conference.

List of New Projects and Activities in Place and Main Objective(s)

Most of the new projects have been launched in 2022 and 2023 (after the Pan-GASS and CFMIP-GASS conferences): EUREC4A-MIP, Cumulus friction, COMBLE, MOSAiC, Deep organization, and DYAMOND.

List of New Projects and Activities Being Planned, including Main Objective(s) and Timeline, Lead(s)

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Science Issues and Collaboration during Reporting Period

Contributions to Developing GEWEX Science and the GEWEX Imperatives

a. Data Sets and b. Analysis

Through its 10 projects, GASS contributes to the release of observational (e.g., UTCC-PROES) and simulation datasets (e.g., Botany cloud ensemble, DYAMOND), to the analysis of field campaigns, simulations from a hierarchy of models [LES, Cloud-Resolving Models (CRM), GCM, Single Column Model (SCM), hindcasts, GSRM] and satellite observations. Advances in process understanding, model initialization techniques (e.g., for the land surface) and representation of model physics (e.g., mesoscale circulation) contribute to improving weather and climate predictions and/or projections.

c. Processes

GASS projects are about process understanding and model representation (e.g., precipitation, clouds, surface fluxes, coupling surface to atmosphere, aerosols, dynamics-physics coupling, organization)

d. Modeling

- GASS projects aim to improve different aspects of atmospheric models and related processes
- GASS uses a hierarchy of models: SCMs, GCMs, CRMs, LES, global CRMs

e. Application

GASS projects intend to improve both weather and climate models and to better understand how atmospheric processes will contribute to future climate changes

f. Technology Transfer

GASS projects intend to transfer improved model treatments to weather and climate center

g. Capacity Building

The GASS email list includes 500+ people (from graduate students to senior scientists in developed and developing countries); junior scientists and scientists with limited resources are also encouraged to participate in GASS projects. GASS has organized an ECR competition at the CFMIP-GASS conference in Paris, and favored oral presentations from early career scientists.

List contributions to the GEWEX Science Goals and plans to include these

Goal # 1 (GS1): Determine the extent to which Earth's water cycle can be predicted. This Goal is framed around making quantitative progress on three related areas posed in terms of the following questions:

1. **Reservoirs:**

What is the rate of expansion of the fast reservoirs (atmosphere and land surfaces), what is its spatial character, what factors determine this and to what extent are these changes predictable?

- LS4P

2. **Flux exchanges:**

To what extent are the fluxes of water between Earth's main reservoirs changing and can these changes be predicted and if so on what time/space scale?

- All Projects

3. **Precipitation Extremes*:***

How will local rainfall and its extremes change under climate change across the regions of the world?

- DCP, DYAMOND, Deep organization, LS4P

Goal # 2 (GS2): 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:

1. **Forcing-feedback understanding:**

How can we improve the understanding of climate forcings and feedbacks formed by energy, water and carbon exchanges?

Cloud and convective processes that matter for water vapor and cloud feedbacks (mixed-phase clouds, anvil clouds, shallow convective clouds, convective organization, polar clouds)

2. **ABL process representation:**

To what extent are the properties of the atmospheric boundary layer (ABL) defined by sensible and latent energy and water exchanges at the Earth's surface versus within the atmosphere (i.e., horizontal advection and ABL-free atmosphere exchanges)?

- EUREC4A-MIP, Cumulus friction, MOSAiC, COMBLE

3. **Understanding Circulation controls:**

To what extent are exchanges between water, energy and carbon determined by the large-scale circulations of the atmosphere and oceans?

- Cumulus friction, LS4P, EUREC4A-MIP, DYAMOND

4. **Land-atmosphere interactions:**

How can we improve the understanding of the role of land surface-atmospheric interactions in the water, energy and carbon budgets across spatiotemporal scales?

- LS4P, DCP

Goal # 3 (GS3): Quantify anthropogenic influences on the water cycle and our ability to understand and predict changes to Earth's water cycle.

1. **Anthropogenic forcing of continental scale water availability:**

To what extent has the changing greenhouse effect modified the water cycle over different regions and continents?

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2. **Water management influences:**

To what extent do water management practices and land use change (e.g., deforestation) modify the water cycle on regional to global scales?

….

3. **Variability and trends of water availability:**

How do water & land use and climate change affect the variability (including extremes) of the regional and continental water cycle?

….

Other Key Science Questions
List 1 – 3 suggestions that you anticipate your community would want to tackle in the next 5-10 years within the context of a land-atmosphere project

- How do the micro- to meso-scale atmospheric processes control global water and energy exchanges (radiation budget, hydrological cycle, atmospheric circulations)?
- What controls cloud phase and precipitation?
- What controls the mesoscale organization of clouds and convection?

Contributions to WCRP including the WCRP Light House Activities
Briefly list any specific areas of your panel's activities in particular to the WCRP Light House Activities (Digital Earth, Explaining and Predicting Earth System Change, My Climate Risk, Safe Landing Cimates and WCRP Academy) https://www.wcrp-climate.org/lha-overview.

- Contribution to the LHA on Digital Earth through the development and analysis of km-scale modeling

Cooperation with other WCRP Projects, Outside Bodies and links to applications
e.g. CLIVAR, CliC, SPARC, Future Earth, etc.

- WGNE, S2S Prediction Project, CFMIP, WCRP Lighthouse on km-scale modeling

Workshops and Meetings

List of Workshops and Meetings Held in 2023
Meeting title, dates and location.

- CFMIP-GASS conference, Paris, 9–13 July 2023, 220 participants
- For meetings associated with each GASS project, see the reports on individual projects, e.g.:
  - International Conference on Tibetan Plateau and High Mountains Energy and Water
  - Exchanges: Climate Impact and Adaptation, Diqing, China, 7–10 August 2023
  - Cloud Tracking Algorithms Workshop, Oxford, UK, April 2023
  - Cloud Organization Workshop, Trieste, Italy, September 2023

    - EVE Berlin Meeting, Berlin, Germany, 4–8 July 2023
- The WWRP/WCRP S2S Summit, Reading, UK, 4–8 July 2023
- and much more.

List of Workshops and Meetings Planned in 2024 and 2025
Meeting title, dates and location and anticipated travel support needs

- Regular GASS Panel meetings in teleconference
- LS4P-II 3rd International Workshop at 2024 AGU Annual Meeting (anticipated travel support of $5000 requested)
- Other meetings or webinar planned by individual projects (no anticipated travel support requested so far)
- ORCESTRA field campaign over the tropical Atlantic on Aug–Sep 2024

Other Meetings Attended On Behalf of GEWEX or Panel in 2023

- GEWEX SSG-35
- Working Group on Numerical Experimentation (WGNE)

Publications during Reporting Period

List of Key Publications

See reports on individual Projects.

2.1.1. GASS Rapporteurs Report

Panel: Global Atmospheric System Studies (GASS) Panel
Rapporteur(s): L. Ruby Leung and Gavin Schmidt

Adherence to GEWEX and Panel's objective(s)

The scientific objective of GASS is to improve the understanding of physical processes in the atmosphere and their coupling to atmospheric dynamics, with the goal of advancing the understanding and prediction of weather and climate. The Panel activities are to promote and facilitate the coordination of projects addressing the goal through the development and use of observations, process studies and a hierarchy of numerical models.

Adherence to GEWEX and Panel's objectives through:
Modeling

- GASS projects aim to improve different aspects of atmospheric models and related processes
- GASS uses a hierarchy of models: SCMs, GCMs, CRMs, LES, global CRMs

Application

- GASS projects intend to improve both weather and climate models and to better understand how atmospheric processes will contribute to future climate changes.

Technology Transfer

- GASS projects intend to transfer improved model treatments to weather and climate centers

Capacity Building

- GASS email list includes 500+ people (from graduate students to senior scientists in developed and developing countries); all GASS project white papers are circulated on this email list; junior scientists and scientists with limited resources are also encouraged to participate in GASS projects. GASS has a YESS member on the Panel and organized an ECR competition for travel support to the 2022 Pan-GASS conference in Monterey, California.

Achievement of annual goals for this reporting period

- **Revision of the GASS Panel composition** (new members: Pier Siebesma, Claudia Stubenrauch, Philip Stier, Louise Nuijens, Felix Pithan; stepped down: Irina Sandu, Carla Gulizia, and Ian Bouttle)
- **10 projects addressing important gaps** in understanding and modeling atmosphere and climate processes (including several new ones stood up last year)
- **CFMIP-GASS meeting** in Paris July 2023 with 220 participants and multiple workshops organized by different GASS projects
- **Cross-WCRP synergies**: GASS-CFMIP collaboration on cloud feedback, GASS-WGNE collaboration on model development, GASS-Digital Earth collaboration on GSRM, GASS-GDAP mutual interests in process diagnostics and observations

Arisen or noted science issues

- The EarthCare project is obviously delayed from previous plans because of the delays in the launch itself (now due for May 2024) – how could this affect the DYAMOND3 plan?
- The MOSAiC nudging experiment is strangely limited. The global nudged runs for 2020 should also be useful for other analyses beyond the Arctic. There must be other measurements elsewhere that could be used to evaluate the models.
- One missing element of DYAMOND might be how these runs could be used to inform coarser resolution model parameterizations.
- What is the "GASS-Digital Earth“ connection? Does it go beyond DYAMOND to include other efforts such as DestinE?

Emerging Science

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Future plans

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Recommendations to Panel

- A few of the projects mention the importance of looking at a hierarchy of models, but this should be more general. Even as we start to see global storm resolving models, we will still need to be running LES, SCM and more standard GCMs in nudged, free running or initialized modes, for exploration of uncertainties and scenarios.
- GASS may consider diversifying the research topics of new projects - e.g., only one project (LS4P) has a strong land-atmosphere focus. How to better connect current cloud/convection focused activities to connect with GEWEX’s broader goals on hydrological cycle and radiation budget?
- Many GASS projects include model intercomparison but participations from operational centers seem limited. How could GASS increase awareness and interest from operational centers?
- Panel should interact more with other sectors like agriculture, hydrology and health, among others

Considerations for SSG

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Additional Remarks

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2.2. GEWEX Data and Analysis Panel (GDAP)

Full Panel Name (Acronym) : GEWEX Data and Analysis Panel (GDAP)
Reporting Period : 01 January - 31 December 20223
Starting Date : …
End Date (where appropriate) : NA
URL : https://www.gewex.org/panels/gewex-data-and-analysis-panel/

Membership

Chair(s) and Term Dates : Tristan L'Ecuyer, 2016 – Present
Hirohiko Masunaga, 2022 – Present

Members and Term Dates : Ali Behrangi 2020 – Present
Helen Brindley, 2022 – Present
Hélène Brogniez, 2020 – Present
Xuelong Chen, 2023 – Present
Eui-Seok Chung, 2019 – Present
Maria Hakuba, 2022 – Present
Andrew Heidinger, 2011 – Present
Seiji Kato, 2017 – 2023
Benoit Meyssignac, 2022 – Present
Brent Roberts, 2023 – Present
Hanii Takahashi, approved by the Panel for 2024 -
Patrick Taylor, 2023 – Present
Yunyan Zhang, 2021 – Present

Panel Objectives, Goals and Accomplishments during Reporting Period

Overall Panel Objective(s)

Continue the legacy of the GEWEX Radiation and GEWEX Data Assessment Panels to coordinate global-scale observations of the fluxes that make up Earth's energy and water cycles to accelerate research into:

- Understanding "How sensitive is the Earth's climate to changes in radiative and other forcings?"
- Assess the current state of the observational capability to document the global water and energy cycle elements in the context of GEWEX science foci with emphasis on their consistency.
- Sponsor supporting ground-based reference networks. Trigger new international initiatives to support GEWEX science objectives and inform the research community at large.

List of Panel Goals

Adjust yearly

- Provide expertise to support the analysis of satellite datasets, many of which were developed with the support of GDAP or GRP [e.g., ISCCP-NG, Global Precipitation Climatology Project (GPCP), Surface Radiation Budget (SRB), SeaFlux, LandFlux]
- Oversee dataset assessments/intercomparison to provide critical uncertainty information for data records and identify gaps and future needs; promote best practices [e.g.,

Cloud/Precipitation/Earth's Energy Imbalance (EEI) assessments, GEWEX Water Vapor Assessment (GVAP)]

- Support ground-based networks [e.g., Baseline Surface Radiation Network (BSRN), International Soil Moisture Network (ISMN)]
- Act as an interface between satellite datasets and GEWEX activities such as the GEWEX Process Evaluation Studies (PROES), GAP, and other GEWEX Panels (GLASS, GASS and GHP)
- Maintain links to other data-oriented working groups and panels (e.g., the Coordination Group for Meteorological Satellites, CGMS)
- Provide guidance to space agencies and raise awareness of upcoming missions
- Represent GEWEX to funding agencies and the within the science community

List of 2 to 3 Key Results
Adjust yearly with respect to goals

- Added three new Panel members (Xuelong Chen, Brent Roberts and Patrick Taylor) to maintain Panel's demographic and topical diversities. Seiji Kato completed his seven year service as a GDAP member.
- Seven new BSRN stations have been supported actively in the process to become fully operational.
- ISCCP-NG released a new Level 1g (L1g) demo for 2021 with 0.05° spatial resolution, 30-minute temporal resolution and no spectral thinning.
- Intercomparison of 18 ocean heat content (OHC) and ocean heat uptake (OHU) rates provided OHU estimates ranging between 0.50 to 0.96 Wm^{-2} over 2005–2019, which is reduced to 0.45 to 0.75 Wm^{-2} when unequal ocean sampling is accounted for.

Other Science Highlights
Not part of the 2-3 key results

- The Earth energy imbalance assessment outputs are used to provide constraints on the recent GEWEX estimate of the global energy budget fluxes in Stephens et al. (2023).
- Compared ISCCP-NG to ISCCP-H cloud vertical distribution and showed ISCCP-NG results agreed much better with state-of-the-art products such as the Atmospheric Infrared Sounder (AIRS)-Laboratoire de Météorologie Dynamique (LMD). This exercise repeated a result from the GEWEX Cloud Assessment Report.

Panel Activities during Reporting Period

List of Panel Activities and Main Result

- ISCCP-NG: Prototype L1g code finished, released on the Cooperative Institute for Meteorological Satellite Studies (CIMSS) GitLab using the MIT License. L1g demo for 2021 was released. Held a virtual meeting with the CGMS International Cloud Working Group (ICWG) to plan its analysis of cloud products from ISCCP-NG generated by ICWG members.
- GVAP-II: Intercomparisons of various water vapor data records showed distinct regional differences over the poles (relative values) and parts of the tropical land. Trends and regression results exhibit differences among the records and relative to expectations, though a subset of records shows agreement despite small breakpoints.
- EEI: The EEI workshop (http://doi.org/10.5270/wcrp-esa-eeia-2023.final_report_brief) enabled entraining a larger community, in particular the geodetic community, where a new group from Bonn is now participating. The workshop also enabled to pinpoint the main

- differences across different OHC products and proposed recommendations, best practices and a way forward to improve the OHC estimates in all approaches.
- BSRN released Time Aggregated data through the Copernicus Climate Data Store (CDS) (VAP WG), in collaboration with Italian Consiglio Nazionale Delle Ricerche (CNR) under a project supported by ECMWF.

List of New Projects and Activities in Place and Main Objective(s)

- The extension of ISCCP-NG to include Meteosat Third Generation (MTG) Flexible Combined Imager (FCI) data has been accomplished by EUMETSAT, but the FCI is experiencing issues and no ISCCP-NG L1g with FCI exists. EUMETSAT says FCI data will start flowing in May 2024.
- After a strong recommendation from the community, the Panel is organizing a new EEI assessment workshop to take place in late 2024 or early 2025.

List of New Projects and Activities Being Planned, including Main Objective(s) and Timeline, Lead(s)

- EUMETSAT will begin processing a 5-year ISCCP-NG L1g data set. This data will be hosted in both National Environmental Satellite, Data, and Information Service (NESDIS) and EUMETSAT cloud environments.
- In the coming 2 years the Panel will write the first version of the synthetic report on the GEWEX EEI assessment activity.
- Cloud tracking data intercomparison is being initiated as a new GDAP activity in collaboration with the Atmosphere Observing System (AOS) and INvestigation of Convective UpdraftS (INCUS) science teams. A relevant workshop will be held at NASA Goddard Institute for Space Studies (GISS_ from 23rd to 25th April 2024.
- A second radiation assessment is being scoped that would address the vertical and spectral dimensions.

Science Issues and Collaboration during Reporting Period

Contributions to Developing GEWEX Science and the GEWEX Imperatives

a. Data Sets
   - In 2023, the EEI assessment panel gathered OHC products and made this dataset freely available on a website to enable the analysis of the EEI to the community
   - G-VAP data archive (http://dx.doi.org/10.5676/EUM_SAF_CM/GVAP/V001)
   - GEWEX Integrated Product
   - ISCCP-NG
   - GEWEX Cloud Assessment Database (https://gewexca.aeris-data.fr/)

b. Analysis
   - Methods for estimating EEI from in situ data and altimetry minus Gravity Recovery and Climate Experiment (GRACE) data
   - Trends, regression and variations in water vapor data records.
   - Consistency frameworks for assessing independent flux estimates
   - Cloud tracking workshop and ISCCP-NG support global cloud lifecycle studies

c. Processes
- Climate change observered in water vapor data
- An analysis of the EEI estimates from OHC products and assessment of their consistency
- Cloud tracking data analysis for convective-scale physics application

d. Modeling
- N/A

e. Application
- The focus is on fully describing and, where possible, understanding stability issues in the data records, to trigger improvements and ultimately enhance consistency and confidence
- High-resolution ISCCP-NG data products for assessment of global km-scale atmospheric models

f. Technology Transfer
- N/A

g. Capacity Building
- N/A

List contributions to the GEWEX Science Goals and plans to include these

Goal # 1 (GS1): Determine the extent to which Earth's water cycle can be predicted. This Goal is framed around making quantitative progress on three related areas posed in terms of the following questions:

1. **Reservoirs:**

What is the rate of expansion of the fast reservoirs (atmosphere and land surfaces), what is its spatial character, what factors determine this and to what extent are these changes predictable?

Changes in total column water vapor (TCWV) were analyzed using the G-VAP data archive v2. To a large extent, associated results exhibit agreement in an increase of TCWV over land and ocean, though with some differences in the extent. Over land, the rate of changes largely stays below expectations from Clausius Clapeyron, likely as expected given a lack of water vapor supply in some regions.

2. **Flux exchanges:**

To what extent are the fluxes of water between Earth's main reservoirs changing and can these changes be predicted and if so on what time/space scale?

The Earth energy imbalance assessment outputs are used to provide constraints on the recent GEWEX estimate of the global energy budget fluxes in Stephens et al. (2023). A better characterization of the EEI enables the reduction of uncertainties in the global energy budget fluxes estimate, in particular those associated to the fluxes of the top of atmosphere radiation budget.

3. **Precipitation Extremes*:***

How will local rainfall and its extremes change under climate change across the regions of the world?

N/A

Goal # 2 (GS2): 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:

1. **Forcing-feedback understanding:**

How can we improve the understanding of climate forcings and feedbacks formed by energy, water and carbon exchanges?

G-VAP assesses the impact of increasing temperature on atmospheric water vapor but hardly improves our understanding of underlying mechanisms. The Earth energy imbalance assessment outputs are used to constrain estimates of the global climate feedback parameter variations over the past decades in Meyssignac et al. (2023a) and are also used to constraint the equilibrium climate sensitivity (Chenal et al., 2022).

2. **ABL process representation:**

To what extent are the properties of the atmospheric boundary layer (ABL) defined by sensible and latent energy and water exchanges at the Earth's surface versus within the atmosphere (i.e., horizontal advection and ABL-free atmosphere exchanges)?

The water vapor assessment effort has the potential to improve our understanding of ABL processes.

3. **Understanding Circulation controls:**

To what extent are exchanges between water, energy and carbon determined by the large-scale circulations of the atmosphere and oceans?

Cloud tracking data analysis is expected in the future to help deepen our understanding of the physical link between moist convection and large-scale atmospheric circulations.

4. **Land-atmosphere interactions:**

How can we improve the understanding of the role of land surface-atmospheric interactions in the water, energy and carbon budgets across spatiotemporal scales?

Future cross-Panel activity with GLASS on closing energy and water cycles over land surfaces

Goal # 3 (GS3): Quantify anthropogenic influences on the water cycle and our ability to understand and predict changes to Earth's water cycle:

1. **Anthropogenic forcing of continental scale water availability:**

To what extent has the changing greenhouse effect modified the water cycle over different regions and continents?

N/A

2. **Water management influences:**

To what extent do water management practices and land use change (e.g., deforestation) modify the water cycle on regional to global scales?

N/A

3. **Variability and trends of water availability:**

How do water & land use and climate change affect the variability (including extremes) of the regional and continental water cycle?

N/A

Other Key Science Questions

List 1 – 3 suggestion that you anticipate your community would want to tackle in the next 5-10 years within the context of a land-atmosphere project

Assessing energy and water cycle closure at the land-atmosphere interface, the factors that influence its variability and how the relevant physics scale from local to regional to global scales (in coordination with GLASS)

Contributions to WCRP including the WCRP Light House Activities

Briefly list any specific areas of your panel's activities in particular to the WCRP Light House Activities (Digital Earth, Explaining and Predicting Earth System Change, My Climate Risk, Safe Landing Cimates and WCRP Academy) https://www.wcrp-climate.org/lha-overview.

Contribution to the LHA on Digital Earth through the development and analysis of km-scale modeling

Cooperation with other WCRP Projects, Outside Bodies and links to applications

e.g. CLIVAR, CliC, SPARC, Future Earth, etc.

- The EEI assessment panel participates in the Explaining and Predicting Earth System Change (EPESC) Lighthouse Activity on analyzing and explaining the current trend in EEI
- Analysis of homogeneity, trends and regression (Explaining and Predicting Earth System Change)

Workshops and Meetings

List of Workshops and Meetings Held in 2023

Meeting title, dates and location.

- 1st EEI Assessment Workshop, held in ESA-ESRIN, Frascati, Italy, 15–17 May 2023

List of Workshops and Meetings Planned in 2024 and 2025

Meeting title, dates and location and anticipated travel support needs.

- 2nd ISCCP-NG/GEO-Ring Workshop, EUMETSAT, Darmstadt, Germany, 29 February–1 March 2024
- Joint GEWEX-AOS-INCUS Convection Tracking Workshop, NASA GISS, New York, New York, USA, 23–25 April 2024
- 18th BSRN Scientific Review and Workshop, Tokyo, Japan, 1–5 July 2024. Hosted by JMA and supported by GEWEX
- The GEWEX Water Vapor Assessment Workshop, date and place TBD
- Workshop on challenges in wet atmospheric processes and cycles (TBD), first half of 2025, UK (details TBD)

Other Meetings Attended On Behalf of GEWEX or Panel in 2023

- Marc Schröder participated in Hydrospace, Lisbon, Portugal, 27 November–01 December 2023 (as G-VAP co-chair) and in the WCRP Open Science Conference
- Benoit Meyssignac, M. Hakuba, T. Boyer and S. Kato presented "Mean, trend, variability and uncertainty in Earth's Energy Imbalance over the last two decades", WCRP Open Science Conference, 23 Oct 2023, Kigali, Rwanda
- Benoit Meyssignac, S. Bony, T. L'Ecuyer, J. Polcher, R. Roca, C. Stubenrauch, G. Stephens presented "The energy cycle (or the water-energy cycle with an energy perspective)" GCOS, WCRP meeting, 22–23 June 2023, Paris, France

- Andy Heidinger gave an oral presentation on ISCCP-NG at the 2023 AGU Meeting (A141-01)
- Tristan L'Ecuyer and Hiro Masunaga attended the 2nd EarthCARE Modeling Workshop, Shuzenji, Japan, 27–29 March 2023
- Tristan L'Ecuyer attended the Integrated Product Workshop on Land-Atmosphere Exchanges, Toledo, Spain, 11–13 April 2023
- Tristan L'Ecuyer and Hiro Masunaga attended the Clouds and the Earth's Radiant Energy System (CERES) Science Team Meeting held in conjunction with the 2023 GDAP meeting, New York City, NY, 17–20 October 2023.

Publications during Reporting Period

List of Key Publications

- (submitted) Trent, T., et al., 2023, Evaluation of Total Column Water Vapour Products from Satellite Observations and Reanalyses within the GEWEX Water Assessment, *EGUsphere* [preprint], https://doi.org/10.5194/egusphere-2023-2808.
- Chenal, J., Meyssignac, B., Ribes, A., & Guillaume-Castel, R., 2022, Observational Constraint on the Climate Sensitivity to Atmospheric CO2 Concentrations Changes Derived from the 1971–2017 Global Energy Budget, *Journal of Climate*, 35(14), 4469-4483. Retrieved Jul 13, 2022, from https://journals.ametsoc.org/view/journals/clim/35/14/JCLI-D-21-0565.1.xml
- Marti, F., Blazquez, A., Meyssignac, B., Ablain, M., Barnoud, A., Fraudeau, R., Jugier, R., Chenal, J., Larnicol, G., Pfeffer, J., Restano, M., and Benveniste, J., 2022, Monitoring the ocean heat content change and the Earth energy imbalance from space altimetry and space gravimetry, *Earth Syst. Sci. Data*, 14, 229–249, https://doi.org/10.5194/essd-14-229-2022.
- Hakuba, M. Z., Frederikse, T., and Landerer, F. W., 2021, Earth's Energy Imbalance From the Ocean Perspective (2005–2019), *Geophys. Res. Lett.*, 48, e2021GL093624, https://doi.org/10.1029/2021GL093624.
- Johnson, G.C., Landerer, F.W., Loeb, N.G. et al., 2023, Closure of Earth's Global Seasonal Cycle of Energy Storage. *Surv Geophys*, https://doi.org/10.1007/s10712-023-09797-6
- Stubenrauch, C.J., Kinne, S., Mandorli, G. et al., 2024, Lessons Learned from the Updated GEWEX Cloud Assessment Database. *Surv Geophys*, https://doi.org/10.1007/s10712-024-09824-0.

2.2.1. GDAP Rapporteurs Report

Panel: GEWEX Data and Analysis Panel (GDAP)
Rapporteur(s): Bob Su and Susanne Crewell

Adherence to GEWEX and Panel's objective(s)

Considering the mission of GDAP, "Observation-centric, climate-oriented, consistency-driven, global, research-focused", the Panel has stayed true to both GEWEX and the Panel objectives, especially regarding assessing global data products and ground-based networks. The recent Energy Balance Workshop at the International Space Science Institute (ISSI) triggered several developing research papers and noteworthy progress has been made on ISCCP-NG are indicative of the time and effort from the GDAP members.

Achievement of annual goals for this reporting period

Product assessment has reached some key milestones within the last year, specifically the second water vapor assessment (GVAP) and the precipitation assessment, which will enter a holding pattern with consideration of new activities sometime in the future. The EEI Assessment continues to evolve, attracting attention from key researchers to workshops and meetings. Further progress in respect to cloud monitoring has been made (ISCCP-NG). GDAP has connected to all the other GEWEX Panels or plans to, in some way. In addition, new members to the Panel will provide strong connections to future radiation budget missions (Libera and Far-infrared Outgoing Radiation Understanding and Monitoring, or FORUM) and more ocean expertise. Furthermore, strong networking with other WRCP projects and space agencies took place. Support to ground-based networks is mainly directed at BSRN.

Major accomplishments and results in reporting period

GDAP coordinated the development and release of a level 1 test product from the ISSCP-NG project. This test data will be used to assess the fine resolutions (0.05 degree and 30 minute) ability to capture convective elements. An EEI study has demonstrated that Ocean Heat Uptake (OHU) estimates exhibit a significant increase of 0.4 Wm^{-2} per decade over 2002–2020 consistent with CERES Energy Balanced and Filled (EBAF) TOA flux.

Arisen or noted science issues

From the presentation to the SSG, it is noted that the Integrated Project has essentially been completed, with partial success of collecting data, but not satisfactorily balanced. The data are available and useful, but no new work is planned. The NASA Energy and Water Cycle Study (NEWS) optimization and balancing project (L'Ecyuer is the Pricipal Investigator) should be tracked within GDAP for supplemental use alongside the Integrated Project data.

Emerging Science

- Panel member Benoit Meyssignac will be working cross Panel on EEI.
- New Panel member Brent Roberts brings ocean retrieval experience and may help GDAP consider ocean closure assessment collaborations (as in the land side) and perhaps develop the Ocean Flux workshop discussed by Tristan.
- Developing fine resolution satellite products in collaboration(s) with GHP's RHPs is a very good direction, but it needs a dedicated lead. New metrics are required for bringing this together with high-resolution modelling, and cloud tracking is an interesting approach that could be widened to broader features.

Future plans
Extending ISCCP L1g through 2023 in order to test the algorithm through satellite platform changes. Also planning a comprehensive comparison of ISCCP-NG with ISSCP from 2020 on.

Assessment of convective object tracking methods (related to UTCC and km-scale modeling activities) (workshop in spring 2023; GDAP lead: Thomas Fiolleau)

Panel Crosscuts
- GASS: Scoping activity centering on convective organization in models and satellite observations; applying simulators to assess representation of clouds and convection in km-scale global models (both anticipated to start spring 2023 and run ~3 years; lead TBD).
- GLASS: Assessing the consistency between surface energy and water fluxes and temperature/soil moisture variations at local, regional and global scales (workshop in April 2023; analysis from 2024–26; lead TBD).
- GHP: Coupling hydrology-motivated high time/space resolution satellite precipitation products to Regional Hydroclimate Products (RHPs) (early 2023–2026; lead TBD)

Recommendations to Panel

- Extend land closure assessment development (collaborative with GLASS) to also include a component for ocean (perhaps collaborating with a CLIVAR group) and polar closure (perhaps collaborating with the Climate and Cryosphere project, CliC).
- A polar connection seems to be needed, regarding Upper Troposphere–Lower Stratosphere (UTLS) as well as cryosphere data.
- Include (weather) radar expertise in the Panel, which would nicely link to GPEX and might be shared with GHP. Diversity in expertise should be considered (here, but also across the Panel), perhaps utilizing YESS connections to also incorporate some early career researchers.
- Follow up on emerging ground-based network with high quality standards, e.g., ISMN, the Aerosol, Clouds and Trace Gas research infrastructure (ACTRIS), and foster their expansion, e.g., BSRN.
- GDAP should be connected to ESMO; for example, bringing observationalists and modelers together on assessment activities and best practices regarding the data.

Considerations for SSG

Should follow up on the future crosscuts (discussed above), such that the TBD Leads are identified and the project planning begins.

Additional Remarks

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2.3. GEWEX Hydroclimatology Panel (GHP)

Full Panel Name (Acronym) : GEWEX Hydroclimatology Panel (GHP)
Reporting Period : 01 January - 31 December 2023
Starting Date : ….
End Date (where appropriate) : N/A
URL : https://www.gewex.org/panels/gewex-hydroclimatology-panel/

Membership

Chair(s) and Term Dates : Paola Arias, 2023 – Present
Ali Nazemi, 2020 – Present

Members and Term Dates : Michael Bosilovich, 2023 – Present
Rowan Fealy, 2021 – Present
Li Jia, 2019 – Present
Venkataraman Lakshmi, 2023 – Present
Santosh Pingale, 2022 – Present
Andreas Prein, 2019 – Present
Joshua Roundy, 2020 – Present
Vidya Samadi, 2019 – Present
Anna Sörensson 2021 – Present
Ivana Stiperski, 2019 – Present
Zhongbo Su, 2023 – Present
Qiaohong Sun, 2023 – Present

Panel Objectives, Goals and Accomplishments during Reporting Period

Overall Panel Objective(s)

To understand and predict continental to local-scale hydroclimates for hydrologic applications by concentrating on improving our understanding of environmental water and energy exchanges at the regional scale to form an integrated perspective.

List of Panel Goals
Adjust yearly

GHP comprises four different types of projects: (1) Regional Hydroclimate Projects (RHPs), aiming at understanding and predicting hydroclimatology in a specific region; (2) Cross Cutting 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. GHP currently includes seven RHPs, seven CCs, one Network and two Data Centers at different stages of development. The current lineups for the four types of projects are:

- RHPs: Global Water Futures (GWF), Baltic Earth, Regional Hydrology Program for the Andes (ANDEX), Third Pole Environment-Water Sustainability (TPE-WS), Humans and Hydroclimate in the United States (H_2US), the Asian Precipitation Experiment (AsiaPEX), and the Central Asia Initiative. Among these, GWF and Baltic Earth are mature RHPs; ANDEX, TPE-WS, H_2US and AsiaPEX are initiating RHPs; and Central Asia is a prospective RHP. Science Plans for TPE-WS, H_2US and AsiaPEX were reviewed and approved by the panel during this current reporting period (2023).

- CCs: the Transport and Exchange Processes in the Atmosphere over Mountains Experiment (TEAMx), the second phase of the International Network for Alpine Research Catchment Hydrology (INARCH-II), Determining Evapotranspiration (dET), Flood CC, GEWEX Groundwater Initiative, Global River Network Observational and Modeling Initiative, and Precipitation over Mountainous Terrains (MOUNTerrain). Among these, TEAMx and INARCH-II are fully operational; dET is the oldest initiating CC in the Panel. dET's Science Plan was approved in 2022; however, the Panel raised some comments in 2022, which triggered a revision in dET's Science Plan in 2023. The revised proposal was reviewed by the Panel in 2023 and informal peer-review comments were provided to the dET leadership. The Panel currently awaits response and did not receive the 2023 annual report from this activity. Flood CC is another initiating CC in the Panel. The other three activities are envisioned CCs. Envisioned CCs are excluded from annual report writing until they are shaped more firmly.
- Current network and data centers include the Pannonian Basin Experiment (PannEx), the Global Precipitation Climatology Centre (GPCC) and the Global Runoff Data Centre (GRDC). These activities are fully operational.

Below, the highlights from each of these activities during the reporting period are highlighted individually with the same order that they are referred to above. Substantial effort was made to avoid redundancies and repetitions; as a result, although some reporting items may have relevance to multiple report headings, they were only mentioned once under the most relevant heading.

List of 2 to 3 Key Results
Adjust yearly with respect to goals

GWF
- The Canada Water Agency has been proposed, with a transition office in place.
- Advances are made in several hydrological modeling systems toward the development of national water forecasting capabilities.
- GWF Observatory (GWFO) is now funded, which provides continuation in the GWF data collection and related science.

Baltic Earth
- Special Issue in *Oceanologia* on the 4th Baltic Earth Conference in Jastarnia, Poland
- Special Issue in *Estuarine and Coastal Shelf Science* on the International Conference on River Mouth Systems

ANDEX
- The Annual ANDEX meeting in Santiago, Chile (3–5 May 2023), which coined the two strategic directions of ANDEX: water security for Andean populations and reduction of risks associated with high-impact hydroclimatic events.
- ANDEX now involves 400+ new members and a young researcher network on Andean hydroclimatology.

TPE-WS.
- Science Plan approved.
- TPE-WS assessed the spatiotemporal patterns and mechanisms of the net ecosystem exchange (NEE) in the Tibetan Plateau.

AsiaPEX
- Review paper in BAMS published.
- Science Plan approved.

H_2US

- The GHP approved the plan of the US-RHP for Food, Energy and Water Security in the Anthropocene. This RHP was thereafter renamed Humans and Hydroclimate in the United States (H_2US) and became an Initiating RHP in September 2023.
- H_2US Affinity Group grew to 168 members and they continue to increase their human and topical diversity.

Central Asia

- Initial leadership group established.
- Submitted a proposal to DOE.

TEAMx

- The second version of the Numerical Modelling Plan (NMP) has been finished.
- A new task team has been initiated to work out the details on how to implement the TEAMx Observational Campaign (TOC).

INARCH-II

- The Common Observing Period Experiment (COPE) is now well underway, with data being collected and the models under preparation for their initial runs.

Floods

- The first Global Flood Crosscutting project was held virtually on Sept. 22, 2023. Around 80flood researchers and scientists participated.
- Ten flood experts moderated the Flood CC workshop scientific sessions, and the sessions were summarized to reflect the overall goals of the Flood CC initiative.

PannEx

- A new special issue of the journal *Atmosphere* on climate extremes in the Pannonian basin (https://www.mdpi.com/journal/atmosphere/special_issues/climate_pannonian_basin)
- Meeting organized in the framework of the European Cooperation in Science and Technology (COST) Action CA20108 - FAIR NEtwork of micrometeorological measurements (FAIRNESS), and conferences organized by the Hungarian Meteorological Service, the University of Novi Sad, Serbia (supported by the EU H2020 Program in the framework of EXtremeClimTwin project) and the Faculty of Agrobiotechnical Sciences Osijek, Josip Juraj Strossmayer University of OsijekPh.D. short course at the ELTE Eotvos Lorand University on micrometeorology (title: Probing at the Earth's Surface under the Conditions of Climate Change)

GPCC

- Increase in the number of quality-controlled stations and data records. The goal is to fully automatically download and import the data into the database.

GRDC

- Web Application is completed and accessible online at https://mrb.grdc.bafg.de/.
- Updating the station-based watershed boundaries (accessible from GRDC Data Portal).
- Making GRDC fair, by providing GRDC stations as an extension to the Caravan dataset.

Other Science Highlights

Not part of the 2-3 key results

GWF

- Completed laboratory, theoretical, fieldwork, community research activities, modeling, visualization, sensor and tool development under GWF program.

ANDEX

- ANDEX has made multiple disseminations of its findings on hydroclimatology in the Andean region.

TPE-WS

- Through combined data gathering and modeling studies, it was found that Alpine meadow areas experienced strong increases in carbon sequestration mainly because of increasing temperatures, while alpine steppe areas had weak increases mainly due to increasing precipitation. Carbon sequestration capacity of alpine grasslands on the plateau has undergone persistent enhancement under a warmer and wetter climate (Wang et al., 2023).

TEAMx

- Multiple groups working on TEAMx model intercomparison studies have presented their work at the International Conference on Alpine Meteorology in June in St. Gallen (Switzerland).
- The “TEAMx Backbone” has been established: It consists of instrumentation with secured funding to be deployed during the TOC. Overall, the ‘Backbone’ serves as a planning tool, based on which research groups participating in the TOC can optimize the distribution of their resources complementing available (secured) instrumentation.

INARCH-II

- Contributions to the INARCH-II ESSD special issue continue.
- AlpSnow (https://alpsnow.enveo.at/) intends to contribute to INARCH-II by providing a full portfolio of high-resolution satellite products (albedo, grain size, wet snow area) for the COPE in the INARCH-II Alps basins.

PannEx

- Questionnaire on transferable skill assessment.

GPCC

- Contributions to the WMO Statement on the Status of the global/regional Climate, and the BAMS State of the Climate. Production of the second version of a homogenized precipitation analysis for Europe based on automatically homogenized (break detection and correction) data.

GRDC

- GRDC data and products have been used in WMO’s State of Global Water Resources reports.

Panel Activities during Reporting Period

List of Panel Activities and Main Result

GWF

- Comprehensive briefing book: “Realising Global Water Futures: a Summary of Progress in Delivering Solutions to Water Threats in an Era of Global Change”
- Outreach through “Science Futures” webpage
- Implementation of an intersectional and balanced strategy in water research
- Women Plus Water lecture
- Knowledge co-creation with Indigenous Communities: Indigenous Water Gathering

Baltic Earth

- Science Plan 2017 is being updated and is expected to be published by May 2024. This involves an assessment and, as appropriate, a modification and termination of existing Grand challenges, Working Groups and research topics, and the installation of new ones.

ANDEX

- ANDEX is growing substantially, with a number of prospects for future regional and international collaborations formed in 2023 and will continue to be shaped in 2024.

Central Asia

- The activity is going toward developing a regionally-based network of experts that are committed to work with partners to advance this effort.
- During 2023, the activity began a pre-proposal to the US Department of Energy for the possible deployment of its state-of-the-art instrument, the Atmospheric Radiation Measurement Climate Research Facility. The pre-proposal was submitted in February 2024.

TEAMx

- The Coordination and Implementation Group (CIG) continues to oversee TEAMx activities. The CIG has increased its meeting frequency.
- The Scientific Advisory Board has provided valuable feedback on the latest developments of TEAMx during the workshop in June 2023.
- Six scientific Working Groups bundle their efforts to work on the following topics: Atmospheric Chemistry, Mountain Boundary Layer, Mountain Climate, Orographic Convection, Surface Atmosphere Exchange, and Waves and Dynamics. The Working Group leaders report regularly (twice-yearly) to the CIG.
- Work on model intercomparison has seen substantial progress: teams working on cold-air pools, thermally-driven winds and transport as well as orographic convection have selected case studies from the past and begun work on numerical simulations from high-resolution models.

INARCH-II

- Initialization of COPE and ongoing fieldwork activities at most INARCH-II basins.
- Model development, application and testing continues across INARCH-II research basins.

Floods

- Discussion has taken place on the workshop outcomes, results and other approaches to move the initiative forward.
- The critical challenges of flood generation mechanism, monitoring and modeling are discussed and articulated in a commentary paper to guide Flood CC proposal development.

PannEx

- The FAIRNESS action aims to improve standardization and integration between databases/sets of micrometeorological measurements that are part of research projects or local/regional observational networks established for special purposes (agrometeorology, urban microclimate monitoring). Budget is available only for organizing meetings and short-term scientific missions. A summer school related to filling gaps in micrometeorological data was organized at the end of August 2023.
- The webpage of PannEx was updated: https://pannex.org/.

GPCC

- Data acquisition activities at bilateral meetings, e.g., visits from other met service delegations at the Deutscher Wetterdienst (DWD).
- Participation in training activities, conferences and workshops.
- Work on further integration of data from open data portals.

GRDC

- Continued data acquisition from National Hydrological Services.

List of New Projects and Activities in Place and Main Objective(s)

GWF

- Proposal submitted on “Global Water Futures Observatories” (GWFO): 64 instrumented basins, lakes, rivers, and wetlands, 15 deployable observation systems and 18 state-of-the-art water laboratories.

ANDEX

- Formation of ANDES C2H (Climatology, Cryosphere, and Hydrology in the Andes), aiming at bringing scientists together around the dynamics of the water cycle and its interactions with climate forcing and changes along the Andes Cordillera.
- OBSERVATORIO ANDINO is a free web platform reporting daily snow cover variations in the central Andes of Chile and Argentina (27°–37°S).
- International Joint Laboratory (IJL) ALTIPLANO is a new Joint Laboratory to study the links between environmental and human health, as well as the use of water resources such as lakes, peat lands, and aquifers in the context of mining, urban pressure and global change.

AsiaPEX

- An AsiaPEX field campaign focused on the processes involved in high moist static energy air mass over the Northeastern Indian subcontinent is in the preparation phase. It will conduct a series of four times daily radiosonde observations spanning the region from Bangladesh to Assam, India. The main observation period will be from May to June in 2024. This will be conducted under the auspices of the South Asian Hydro- Meteoro-Climatological Observation Network (SOHMON) within AsiaPEX, led by Dr. Terao (Kagawa University) and Dr. Hayashi (Kyoto University).
- Collaboration with South Asian countries under the South Asian Meteorological Association (SAMA) and Indian Institute of Tropical Meteorology (IITM) takes place for intensive observation of monsoon rain mechanisms.

Central Asia

- If the Atmospheric Radiation Measurement (ARM)-Mobile Facility experiment proposal to DOE is successful, it can lead to a yearlong land-atmosphere/Boundary layer observation.

TEAMx

- Stefano Serafin (University Vienna, Austria) has been granted an Austrian Science Fund (FWF) grant for his project targeting boundary layer parameterizations over mountains: DEmonstrating Parameter estimation with ENsemble-based Data Assimilation for Boundary-Layer modElling over mountains (DEPENDABLE).
- Dino Zardi (University of Trento, Italy) has been granted a project focusing on Disentangling mechanisms controlling atmospheric transport and mixing processes over mountain areas at different space- and timescales (DECIPHER). This project includes an observational campaign, taking place during summer 2024 and/or 2025 at Monte Baldo and Col Margherita (Adige Valley Target Area).
- Miguel Teixeira (University of Reading, UK) has been awarded a Leverhulme Trust grant to work on a project using clear-air turbulence data to test a new diagnostic for fluid flow instability and turbulence generation that replaces the Richardson number. Data obtained from aircraft observations during the TOC will be used to test the diagnostic in a boundary layer setting.

- Atmospheric boundary-layer modeling over complex terrain (ASTER, Manuela Lehner, UIBK, Prinicipal Investigator) is formally terminated.

INARCH-II

- The COPE initiative

List of New Projects and Activities Being Planned, including Main Objective(s) and Timeline, Lead(s)

GWF

- GWF Synthesis team is collating user questions to answer in the synthesis chapters.
- GWFO is monitoring the extreme weather and water conditions experienced during the prior months.

ANDEX

- ANDEX is currently focusing on drafting its Scientific Plan for the 2024–2033 period, in which a number of disciplinary and transversal projects are identified.
- New project on understanding “Current climate and glacier changes and related hydrological impacts in the Santa Cruz River catchment, Southern Patagonian Andes” was recently initiated.

H_2US

- The H_2US Affinity Group is working towards using existing data sets–such as the National Center for Atmospheric Research (NCAR)- United States Geological Survey (USGS) produced CONUS404, a 43-year, 4-km resolution simulation of the hydroclimate over the CONUS–to initiate collaborative analyses driven by the questions identified in our Summary Level Science Plan.

AsiaPEX

- Collection of sections in the GEWEX OSC 2024, including collaboration session with GPEX.
- Plan for the model intercomparison project focusing on the Asian hydroclimatological system and for the AMY-II reanalysis product.

Central Asia

- The development for a small team to lead this effort has been initiated and consists currently of Maksim Kulikov, University of Central Asia, Bishkek, Kyrgyz Republic; Sagynbek Orunbaev, American University of Central Asia, Bishkek, Kyrgyz Republic; Michael Brody, International Agricultural University, Tashkent, Uzbekistan.
- There is a need for assessments of datasets related to (global) water and energy fluxes and their consistency (difficult to fund, but essential), along with their uncertainty and error characterization and to develop support of in situ observational networks in the long-term, complemented by mutually supportive modeling and process studies.
- Major conclusions included the need for meteorological stations, regional data and data sharing to be regional, rather than country-based.
- Priorities for GEWEX for the region include both observations and modeling, such as supporting the development of better precipitation observations/networks/measurements (covering the region and elevations). These efforts should lead to reductions in critical climate uncertainties in policy-relevant timeframes that can influence decisions on investments in adaptation, especially in expensive new water infrastructure.

TEAMx

- The Universities of Vienna and Innsbruck, Karlsruhe Institute of Technology, DWD and MeteoSwiss have submitted a WEAVE-Proposal. The ambitious project aims at providing a high-resolution analysis of the TOC based on ICON model simulations. The resulting gridded dataset covering the TEAMx study region with a sub-kilometer grid will be made publicly available. Principal Investigator: Stefano Serafin.

INARCH-II

- COPE and the follow-on model testing and evaluation, sensitivity analyses, and diagnostic and predictive modeling are planned for. Timeline as follows: forcing and diagnostic data to modeler by October 2024, final runs conducted over fall 2024–spring 2025, and presentations at conferences: International Mountain Conference at Innsbruck, September 2025; American Geophysical Union Meeting, December 2025, and possible special issue journal for publications.

Floods

- The Flood CC team will convene/chair a flood session at the GEWEX OSC.

PannEx

- The long-waited ESA call had to be canceled in autumn 2023 because no submission went through due to the lack of experience with the ESA-proposal system. We hope to renew the call in 2024 with the following main objectives: (1) supporting sustainable irrigation, (2) preserving ecological services, (3) monitoring of the soil and the biomass production, drought early warning system, (4) urban climate, (5) estimating the components of the surface energy budget and (6) using evaporation products.

GPCC

- One of the technical assistants will retire and a new one must be hired.
- GPCC will use more open data portals to access data from national and regional services.
- A proposal has been submitted to participate in a project working on water security in southern Africa

GRDC

- GRDC Supports WMO activities with GRDC datasets such as WMO Hydro SOS (Status and Outlook System) to provide selected datasets to the WMO WHOS system, and contribution to Arctic-Hydrological Cycle Observing System (HYCOS) Phase II. GRDC has already participated in Phase I.

Science Issues and Collaboration during Reporting Period

Contributions to Developing GEWEX Science and the GEWEX Imperatives

h. Data Sets

GWF

- Development of open access data and GWFNet metadata catalog

ANDEX

- Daily Snow Cover Area (SCA) from Moderate Resolution Imaging Spectroradiometer (MODIS) sensor for the main watersheds in central Chile and central-western Argentina (https://observatorioandino.com/nieve/)

TPE-WS

- 500 datasets have been published in the National Tibetan Plateau Data Center (Third Pole Environment Data Center), with open data sets of approximately 230 and a total size of about 55 TB.

AsiaPEX

- New datasets from Himalaya Precipitation Study (HiPRECS) and Strong Observational Activity over the North-eastern Indian subcontinent (SOHMON) projects. A long-term high-accuracy (1/30 degree) precipitation dataset for the Third Pole region was shared (Jiang et al., 2023).

- In situ data collected at 53 stations in western Tibetan Plateau over 2017–2020 was also shared (Yang et al., 2023), as was a method to remove interference in spaceborne radar data for high altitude precipitation detection (Hitose et al., 2023).

TEAMx
- New instrumentation is being tested and installed to extend the i-Box supersite for the TOC in the Inn Valley Target Area.The pre-campaign, which has taken place, helps to decide where to deploy instrumentation during the TOC. A publication (Pfister et al.) is in review with Met Z.
- Publication of (first) data sets from the pre-campaign in the Inn Valley: Gohm et al. (2022; https://zenodo.org/record/7118576#.Y1wtHC-21MA). Others will follow.
- The data management strategy for both observational and modeling data has been further developed: long-term access to TEAMx data will be provided via the Earth Data Portal.

INARCH-II
- INARCH-II data are available at https://inarch.usask.ca/datasets-outputs/mountain-hydrometeorological-data.php.

PannEx
- Improvement of standardization and integration between databases/sets of micrometeorological measurements within the PannEx region has taken place.

GPCC
- The second version of a homogenized precipitation analysis for Europe was produced, publication pending.

GRDC
- GRDC-Caravan 6th extension: Streamflow from 5357 catchments and 25 countries, spans 1950–2023, and is publicly available on Zenodo: https://zenodo.org/records/10074416.

b. Analysis

AsiaPEX
- New understanding of differences in precipitation characteristics (drop size/phase) over the Asian region was produced using the Global Precipitation Measurement (GPM) product (Yamaji and Takahashi, 2023).
- Localized strong warming over winter northern Japan was analyzed to identify an impact of sea ice retreat (Tamura and Sato, 2023).
- Impacts of sub-seasonal Indian monsoonal heating on East Asian summer rainfall were evaluated (Li et al., 2023).TEAMx
- Analysis of turbulence anisotropy data from various data sets including those in the TEAMx study region in the TEAMx project, Unicorn (European Research Council Consolidator Grant, Ivana Stiperski, University of Innsbruck, Pricipal Investigator).
- The TEAMx project "INvestigating ThE suRFACe Energy balance over mountain areas" (INTERFACE) started on 1 May 2022. The project investigates energy balance under closure across the TEAMx study region and will provide two additional flux stations (Lorenzo Giovannini, University of Trento, is the Principal Investigator, aided by Mathias Rotach, University of Innsbruck; and Stefano Tondini, Eurac Research). A first ‘start-up meeting’ took place in July in Trento.

- A TEAMx project, Exposing spatio-temporal Structures of Turbulence in the Atmospheric Boundary Layer with In-Situ measurements by a fleet of Unmanned Aerial Systems (ESTABLIS-UAS), began in 2022. Norman Wildmann (German Aerospace Center DLR), Principal Investigator, plans to measure highly resolved flow structures with a fleet of Uncrewed Aircraft Systems.

INARCH-II

- INARCH-II has analyzed and quantified the sensitivity of mountain snow hydrology regimes around the world. INARCH-II continues to examine the performance of alpine snow models in simple alpine environments by comparison of model outputs to diagnostic measurements: https://inarch.usask.ca/science-basins/cope.php#Modellingsoftwaretools.

GPCC

- A study of the mode of operation on extreme precipitation is in progress, i.e., first doing the analysis and subsequently calculating the extreme indices, or vice versa.

c. Processes

GWF

Many projects in GWF are focused on improving process understanding and parameterization: (https://gwf.usask.ca/impc/;https://gwf.usask.ca/prairiewater/; http://www.mountainwaterfutures.ca/; https://uwaterloo.ca/agricultural-water-futures/; https://gwf.usask.ca/projects-facilities/allprojects/p1ph2-hydrology-ecology-feedbacks.php; https://gwf.usask.ca/projects-facilities/allprojects/p1ph2-bwf-wildfire.php).

AsiaPEX

- Advances in understanding impacts of hydro-climatological processes over different land surfaces, localized strong warming and humidification on snow under a warming climate (Tamura and Sato, 2023), cloud resolving model calculations (Hirata et al., 2023), impacts on snow cover and surface temperature on Eurasian Continent (Komatsu et al., 2023; Takaya et al., 2023) and application of land surface model to the evaluation of water balance over the Himalayan region (Buri et al., 2023).

TEAMx

- To provide information for the experimental work, several climatologies are being compiled for the TEAMx region. These include studies of convection initiation from lightning data, convection from radar data (WG Orographic Convection) and cold-air pools from surface and remote sensing instrumentation. The Plan for the TOC sets out how the proposed research will target specific physical processes and lead to new understanding (through novel observations, simulations or a combination of both).

INARCH-II

- INARCH-II has made significant advancement in alpine hydro-meteorological process understanding and representation in models.

GPCC

- Review schedule of routines to produce near-real time products.

d. Modeling

GWF

- Advances in hydrological, ecological, land surface and atmospheric model development are summarized in https://gwf.usask.ca/core-modelling/ and https://gwf.usask.ca/impc/.

ANDEX

- ANDEX continues to collaborate with SAAG (South America Affinity Group; https://ral.ucar.edu/projects/south-america-affinity-group-saag) and CPAmSur (Convection Permitting Modelling for South America). The activity is working on two review papers related to climate and hydrological modeling in the Andes and recent progress and challenges of modeling in the Andes.

TPE-WS

- Most climate models show systematic cold biases during the snow-covered period over the Tibetan Plateau (TP), which is associated with snow and surface albedo overestimations. A new snow cover fraction (SCF) and albedo schemes for shallow snow developed can significantly reduce the cold biases in the surface skin temperature (from −4.39°C to 0.19°C for the TP mean) and 2-m air temperature (from −4.48°C to −1.05°C for the station mean) during the cold season (October to May of next year) in the study region. This work provides guidance for advancing the snow-related physics in climate models and the improved Weather Research and Forecasting (WRF) model couldfacilitate weather forecasting and climate prediction for the plateau region. (Zhou et al., 2023).

AsiaPEX

- Cloud resolving model calculation showed its great impact on the understanding of heavy precipitation processes in remote areas (Hirata et al., 2023).
- MRI-AGCM3.2 was used to evaluate soil moisture impact on the heatwave in current and future climate in India (Ganeshi et al., 2023).
- Application of land surface model to the evaluation of water balance over the Himalayan region was carried out (Buri et al., 2023).

TEAMx

- Four TEAMx-endorsed modeling projects are underway: ASTER (Manuela Lehner, University of Innsbruck), Improved LAI EsTImaTIon for weather forecAsts [LAETITIA, Stefan Schneider, Central Institute for Meteorology and Geodynamics (ZAMG), Principal Investigator], 'The Atmospheric Boundary Layer in NWP' (Jürg Schmidli, Principal Investigator, Goethe University Frankfurt) and 'kmMountains' - Mountain Climate at the Kilometer-Scale Resolution (PRACE - Partnership For Advanced Computing In Europe,Nikolina Ban, Principal Investigator, University of Innsbruck). A continuation of the kmMountains project has been successfully funded.

INARCH-II

- INARCH-II developed and advanced the next generation of alpine meteorological and hydrological
- models, conducted Earth system model intercomparisons and proposed new algorithms (https://inarch.usask.ca/science-basins/models-downscaling-tools.php).

e. Application

ANDEX

- Apart from the Observatorio Andino website, ANDEX is working in close collaboration with the Peruvian Geophysical Institute (IGP), the Peruvian Environmental ministry (MINAM), and South American authors of the sixth cycle of the Intergovernmental Panel on Climate Change (IPCC) in the creation of the Observatory of Scientific Knowledge on Climate Change (Ciencia Climática).

AsiaPEX

- Recent advances in tropical cyclone prediction over Northwestern Pacific Ocean were reported in two papers (Schreck et al., 2023 and Takaya et al., 2023).

TEAMx

- The current focus of TEAMx is on planning and securing funding for the experimental (observational and modeling) activities in 2024–2025. These plans are being developed with applications in mind.

INARCH-II

- INARCH-II science is implementing Integrated High Mountain Observation and Prediction Systems(IHMOPS) to estimate the sensitivity of the high mountain cryosphere and hydrology to climate change.

f. Technology Transfer

GWF

- GWF works with over 530 partner and user groups to deliver knowledge, scientific advancements and new tools for managing water risks.

AsiaPEX

- Collaboration with Bangladesh and India is occurring to transfer observational methods to local counterparts.

TEAMx

- The TEAMx NMP is being further developed and will include chapters addressing the known challenges and current best-practice recommendations for numerical modeling in complex terrain. The TEAMx Experimental Plan is being developed from a dual perspective of both observation and modeling and the need to integrate and assimilate the two. Plans for the field campaign involve an exceptional range of cutting-edge instrumentation (ground-based and airborne in situ and remote sensing instruments), which will help to provide a three-dimensional characterization of the atmosphere and insight into processes across multiple scales.

INARCH-II

- INARCH-II will work with stakeholders to develop plans to predict future water scenarios.

PannEx

- PannEx is organizing training school to provide knowledge and technology.

g. Capacity Building

Baltic Earth

- Summer and winter schools: https://baltic.earth/schools
- 4th Baltic Earth Winter School, Analysis of Climate Variability
- 9th Baltic Earth Summer School on the Swedish island of Askö, Climate of the Baltic Sea region
- 4th Baltic Earth Conference, young scientists event

ANDEX

- Apart from ListANDEX and JovenANDEX, ANDEX organized a series of webinar series on “Challenges and perspectives of the hydroclimatology of the Andes: From science to policy”.
- Two courses in Peru about interdisciplinarity [in Cusco, supported by Institut De Recherche Pour Le Développement (IRD) and Pontificia Universidad Católica del Perú (PUCP)] and glaciology and water resources [in Huaraz, supported by Instituto Nacional de Investigación en Glaciares y Ecosistemas de Montaña (INAIGEM), Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales (IANIGLA) and IRD] were also organized.

H_2US

- H_2US Participated in the LS4P-II Workshop at AGU in December 2023 to foster coordination and awareness.
- They continued engagement with United States Global Change Research Program (USGCRP) to foster coordination and generate interest and support. They are also in dialogue with program managers in several federal agencies and with NCAR leadership to identify support for H_2US.
- They began engaging in the inter-agency Integrated Hydro-Terrestrial Modeling (IHTM) activities, which may provide opportunities for collaboration and to obtain support.

TEAMx

- Reports were made to the World Weather Research Programme (WWRP) SSC (TEAMx being an Endorsed Project). The Project Coordination Office continuously provides endorsement for TEAMx projects. Members of the Field Observations Committee have submitted applications to use large observational facilities in the TEAMx Observational Campaign.

INARCH-II

- INARCH-II will work with stakeholders to build capacity, enhance forecasting systems, answer questions on water futures and evaluate the sustainability of proposed water management solutions.

PannEx

- PannEx involves Ph.D. students and young scientists.

GPCC

- GPCC participates in training on processing hydrological observations for countries in Central Asia.

List contributions to the GEWEX Science Goals and plans to include these.

Goal # 1 (GS1): Determine the extent to which Earth's water cycle can be predicted. This Goal is framed around making quantitative progress on three related areas posed in terms of the following questions:

1. **Reservoirs:**

What is the rate of expansion of the fast reservoirs (atmosphere and land surfaces), what is its spatial character, what factors determine this and to what extent are these changes predictable?

AsiaPEX

- The impact of the spring surface temperature anomaly has been investigated under the LS4P initiative: the land-surface can be a predictability source in such circumstances.
- Under collaboration in AsiaPEX, Ganeshi et al. (2023) investigated the impact of soil moisture on the frequency and length of heatwave over the Indian subcontinent region using outputs from specially-designed global climate model experiments. It shows the ability of climate models for the diagnostic studies of land surface water and heat reservoirs. However, challenges are still there in the validation of these modeling results by observational data.

TEAMx

- Generally, the better understanding of hydrological processes in mountainous areas will lead to an improved assessment of the reservoirs in these areas (in both atmosphere and land surface). However, no activities are currently planned to specifically address these questions.

INARCH-II

- INARCH-II makes valuable contributions to this goal through its work on mountain snow packs and glaciers and their changes, and to a lesser extent, mountain groundwater and lakes.

GPCC

- The non-real time products Global Precipitation Climatology and Full Data Monthly help to determine the average precipitation over land (Schneider et al., 2017; Dorigo et al., 2021). Based on the continuously enlarged and improved GPCC database, new and improved versions of the non-real time products will be released in future.

2. **Flux exchanges:**

To what extent are the fluxes of water between Earth's main reservoirs changing and can these changes be predicted and if so on what time/space scale?

AsiaPEX

- Validation using ground truth data Is highly challenging especially for the soil moisture.
- Application of land surface models to the evaluation of water balance over the Himalayan region shows the importance of land surface evaporation of high-altitude regions (Buri et al. 2023).

INARCH-II

- INARCH-II focuses on quantifying the sensitivity and changes in the mountain water cycle, including water vapor fluxes driven by sublimation and evapotranspiration, solid fluxes via blowing snow, snow avalanches and glacier ice dynamics and liquid fluxes from melt water movement through snow and ice, infiltration to frozen and unfrozen soils and mountain runoff generation.

ANDEX

- Through collaboration between IGP, ANDEX and GEWEX, Huayao Observatory (Huancayo, Peru) is currently being proposed as a potential GEWEX Land-Atmosphere Feedback Observatory (GLAFO) station. A visit to Huayao Observatory is planned for 2024 (for WCRP, GEWEX and ANDEX members).

TEAMx

- The Orographic Convection Working Group aims to characterize vertical moisture fluxes, cloud base mass fluxes and cloud detrainment rates over complex terrain using ground-based and airborne observations of shallow and deep moist convection over the Alpine range and the forelands during the TEAMx Observational Campaign.
- The Surface-atmosphere Exchange Working Group will investigate latent heat fluxes from a range of surfaces over complex terrain, including forest, agricultural, urban and glacier surfaces.
- The Mountain Boundary Layer Working Group will explore water vapor transport within the boundary layer, as well as exchange at the top of the boundary layer and with the surface below.

3. **Precipitation Extremes*:***

How will local rainfall and its extremes change under climate change across the regions of the world?

GWF

- Advances are available at https://gwf.usask.ca/documents/more-intense-precipitation-in-a-warming-world.pdf
- The Short Duration Extreme Precipitation in Future Climate project website: https://gwf.usask.ca/extreme-precipitation/
- Climate-Related Precipitation Extremes: https://gwf.usask.ca/extremes/index.php

AsiaPEX

- Kim et al. (2023) focused on the hourly extreme precipitation in South Korea after 1973, finding a notable increase in hourly extreme precipitation in recent decades. Liu et al. (2023) utilized high-resolution climate model output from Community Earth System Model (CESM) version 1.2.2, and analyzed future acceleration of precipitation extremes including 1-hr accuracy.

TEAMx

- Recent studies suggest that changes in the large-scale atmospheric circulation might have an important impact on climate extremes in mountain environments. The Mountain Climate Working Group will investigate this topic by analyzing the connection between altitudinal trends of temperature, precipitation and snow cover and large-scale dynamics.
- The kmMountains TEAMx-endorsed project will use high-resolution climate simulations (of order 1 km grid spacing) to improve understanding of precipitation and extreme events over mountainous regions, in particular the effects of continued atmospheric warming.

INARCH-II

- Mountain precipitation is a fundamental aspect of INARCH-II with respect to its phase and amount in high mountains. This includes rain-on-snow events, which can result in extreme flooding in mountain environments.

GPCC

- Under climate change, the hydrological cycle is expected to intensify and precipitation extremes are to occur more frequently. Paper: Masunaga et al. (2019), "Inter-product biases in global precipitation extremes", *Environ. Res. Lett.* 14, 125016

Goal # 2 (GS2): 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:

1. **Forcing-feedback understanding:**

How can we improve the understanding of climate forcings and feedbacks formed by energy, water and carbon exchanges?

AsiaPEX

- Yamaji and Takahashi (2023) compared land-atmosphere feedback for pre-monsoon and monsoon season, and different interactions can be obtained.
- Impacts on snow cover and surface temperature on Eurasian Continent were analyzed by Komatsu et al. (2023) and Takaya et al. (2023).
- Localized strong warming over winter northern Japan has been analyzed to identify an impact of sea ice retreat (Tamura and Sato 2023).

TEAMx

- The overarching aim of TEAMx is to improve process understanding concerning the transport and exchange of energy, momentum and mass across a range of spatial and temporal scales. A major part of this aim involves addressing interactions and feedback.

INARCH-II

- INARCH-II contributes to understanding, modeling and predicting changes in mountain snow cover, glaciers and land cover, which all have critical importance on surface energy balance and climate feedback. Examination of ecosystem fluxes and how they are responding to longer snow-free seasons, declining frozen soils and warmer summers and the upward migration of alpine tree lines is fundamental to INARCH-II.

2. **ABL process representation:**

To what extent are the properties of the atmospheric boundary layer (ABL) defined by sensible and latent energy and water exchanges at the Earth's surface versus within the atmosphere (i.e., horizontal advection and ABL-free atmosphere exchanges)?

TPE-WS

- TPW-WS has studied the atmospheric boundary layer (ABL) on the Tibetan Plateau (TP) to understand surface heat and moisture balances, as well as weather and climate change on the TP and surrounding areas. This study investigated the convective boundary layer height (CBLH) during the pre-monsoon, monsoon and post monsoon periods using radio sounding data. As the monsoon retreated, the maximum CBLH appeared in the western TP. Downward shortwave radiation and net radiation at all stations decreased during this period. Sensible heat flux either increased or remained stable in regions significantly influenced by the monsoon, alongside elevated CBLH. Conversely, sensible heat flux and CBLH decreased in regions less affected by the monsoon. Furthermore, the monsoon-impacted regions exhibited the highest stability of the mid-lower atmosphere during the monsoon period, hindering CBL development. The advance and retreat of the monsoon impact the allocation of sensible and latent heat flux, along with the stability of the mid-lower atmosphere, ultimately influencing the CBLH in different regions of the TP.

AsiaPEX

- Ganeshi et al. (2023) found a revamp of the impact of global warming on the soil moisture perturbations on frequency and duration of extreme temperature events.

TEAMx

- Characterization of the boundary layer above mountainous terrain (the "mountain boundary layer") is central to TEAMx activities. Numerous observational and modeling studies will address exactly this topic. Close links between the Mountain Boundary Layer Working Group and Surface-atmosphere Exchange Working Group will help to specifically link surface and ABL processes.

INARCH-II

- INARCH-II provides datasets for characterizing mountain boundary layer meteorology in otherwise data-sparse regions of the world.

3. **Understanding Circulation controls:**

To what extent are exchanges between water, energy and carbon determined by the large-scale circulations of the atmosphere and oceans?

GWF

- Work in GWF using the WRF atmospheric model has led to important insights (https://doi.org/10.1016/j.atmosres.2022.106380; https://doi.org/10.1002/qj.4434; https://doi.org/10.1175/WAF-D-22-0022.1; https://doi.org/10.1016/j.egyr.2022.05.122).

ANDEX

- Recent ANDEX studies analyzed how regional deforestation impacts the onset of the South American monsoon system, and by consequence, the wet season (e.g., Sierra et al., 2023). Similarly, other studies have focused on the role of climate change on atmospheric moisture transport in the region (e.g., Arias et al., 2023). Future projections of these mechanisms are also under investigation in the framework of the Regional climate model of Institut Pierre Simon Laplace (RegIPSL) modeling team and ANDEX. A particular focus on the Amazon-Andes transition region was given in the study Gutierrez et al. (2024), where the ability of CORDEX models was analyzed, particularly in reproducing spatial rainfall distribution and annual cycle in the region.

AsiaPEX

- Takaya et al. (2023) and Schreck et al. (2023) studied the ability of subseasonal to multi-annual tropical cyclone forecasts, which are highly relevant to the understanding of atmospheric circulation control. Impacts on snow cover and surface temperature on the Eurasian Continent were analyzed by Komatsu et al. (2023) and Takaya et al. (2023). Impacts of sub-seasonal Indian monsoonal heating on East Asian summer rainfall was evaluated (Li et al., 2023).

TEAMx

- Large-scale circulation is of particular interest to the Waves and Dynamics Working Group and Atmospheric Chemistry Working Group. There are already projects planned to investigate the role of gravity waves and mounting venting in pollutant transport.

INARCH-II

- INARCH-II implements regional and continental-scale atmospheric modeling (i.e., through collaborations with the US National Center for Atmospheric Research and Global Water Futures for high-resolution CONUS II WRF simulations) that sheds insight on the controls of circulation patterns on mountain hydrometeorology.

GPCC

- GPCC's Full Data Monthly has a sufficient temporal length—more than 130 years—to investigate connections between circulation indices like El Niño–Southern Oscillation (ENSO), Indian Ocean Dipole (IOD) or North Atlantic Oscillation (NAO) and monthly precipitation totals. Some ENSO sensitive regions were detected in a GPCC-internal analysis like the Maritime Continent, Australia, Amazon Basin, Southwest North America and East and southern Africa.

4. **Land-atmosphere interactions:**

How can we improve the understanding of the role of land surface-atmospheric interactions in the water, energy and carbon budgets across spatiotemporal scales?

GWF

- The GWF network of observatories provides detailed measurements of surface energy and water fluxes.

ANDEX

- ANDEX conducted studies about the impact of the Amazon deforestation in the Amazon-Andes water cycle connectivity (Wongchuig et al., 2023; Sierra et al., 2023). The analysis also includes future projections of the main atmospheric circulation patterns due to climate change and Amazon deforestation (Agudelo et al., 2023).

- ANDEX is working on future projections of the water cycle in the Andes due to climate change and Amazon deforestation. Climate simulations of a coupled Organising Carbon and Hydrology In Dynamic Ecosystems- Weather Research and Forecasting (ORCHIDEE-WRF) model, including floodplains parametrization, is available for the entire South America at 20 km horizontal resolution for the 1996–2020 period.

TPE-WS

- TPE-WS has investigated the spatiotemporal patterns of ground surface temperature (GST) and surface air temperature (SAT) by examining 11 potential factors in three categories in influencing the GST-SAT variations from 1983 to 2019 over the Tibetan Plateau (TP) using boosted regression tree models. The results show that the TP has experienced asynchronous warming in GST and SAT since 2001: a warming hiatus in SAT but continued warming in GST resulted in a significantly increasing trend in GST-SAT (Li et al., 2024).

AsiaPEX

- Buri et al. (2023) applied a land surface model to the evaluation of water balance over the Himalayan region to show the importance of land surface evaporation of high-altitude regions.

TEAMx

- TEAMx brings together cutting-edge observational technology (in situ, remote sensing, ground based and airborne) with the latest modeling capabilities to probe the surface, sub-surface and atmosphere and address this specific research question.
- The TEAMx INTERFACE project will investigate surface energy balance closure in complex terrain and its implications for energy and carbon budgets.
- The TEAMx Unicorn project will use a variety of observational and modeling techniques to try to unify our understanding of near-surface turbulence and how turbulence characteristics (affecting energy, water and carbon exchange) are related to site characteristics.
- Driven by the Surface-atmosphere Exchange and Mountain Climate Working Groups, an effort will be made to increase soil moisture monitoring at TEAMx sites where possible.
- The year-long TEAMx Observational Campaign will have an Extended Observation Period in winter as well as in summer.

INARCH-II

- INARCH-II efforts are helping to bridge scales from field site to headwater basin, river basin, regional and continental, but there remains a critical need for the mountain research observatories and the INARCH-II hydrometeorological, hydrological and hydroglaciological process studies that are conducted there.

Goal # 3 (GS3): Quantify anthropogenic influences on the water cycle and our ability to understand and predict changes to Earth's water cycle.

1. **Anthropogenic forcing of continental scale water availability:**

To what extent has the changing greenhouse effect modified the water cycle over different regions and continents?

GWF

- GWF is focused on characterizing and quantifying the water cycle and its changes in relation to climate change over the major river basins of Canada.

ANDEX

- ANDEX conducted initial studies about the intercomparison of GCMs and Coordinated Regional Climate Downscaling Experiment-Regional Climate Models (CORDEX-RCMs) in the Andean region, including spatio-temporal rainfall patterns (Gutierrez et al., 2024), Southern Annular Mode (SAMS) representation (Olmo et al., 2022) and South American monsoon projections regarding climate change scenarios (Agudelo et al., 2023).

AsiaPEX

- Projections of both annual and extreme rainfall patterns will be an important outcome to understand this issue. At the same time, especially for high mountains, the cryosphere plays crucial roles for the water availability for tributaries through snow melt, though this pattern is also changeable. Collaboration with the cryosphere research community is continuing under the HiPRECS project and by other researchers.

TEAMx

- The Mountain Climate Working Group will partly address this question for the TEAMx study region (i.e., the European Alps). There may be other TEAMx-related projects that will assess similar questions for other mountain ranges. The kmMountains TEAMx-endorsed project is focused on precipitation and climate change in the European Alps, the Himalayas and Tibetan Plateau.

INARCH-II

- INARCH-II focuses on rivers that have mountain headwaters where snow and ice reserves are directly impacted by rising temperatures—these are about 50% of human water supplies around the world.

GPCC

- The recently generated second version of the homogenized precipitation analysis for Europe is free of artificial trends. The remaining trends are associated with climate change. Therefore, this product can be used to investigate the impact of climate change on precipitation amounts and patterns. Briefly, the southern part of Europe is getting drier while the northern parts receive more precipitation. For some regions, opposite trends in different seasons are found.

2. **Water management influences:**

To what extent do water management practices and land use change (e.g., deforestation) modify the water cycle on regional to global scales?

GWF

- GWF focuses on land cover change (i.e., glacier loss, forest and vegetation change, land and water management) in cold regions, which impacts the water cycle and the flow of rivers originating in mountain and cold regions (see https://doi.org/10.1002/hyp.14557; https://doi.org/10.5194/hess-23-3735-2019).

AsiaPEX

- Special emphasis on the ultra-high-resolution model incorporating the anthropogenic effects including water management practices is considered.

TEAMx

- The variety of surface cover within the TEAMx study region will provide valuable observations for the validation of models, which could be used to investigate the link between land use change and the water cycle. As part of the experimental plan, a geo-referenced list and interactive map of existing monitoring stations across the study area is being compiled, including hydrological monitoring stations, snow stations of the avalanche services, meteorological stations and research stations.

INARCH-II

- INARCH-II focuses on land cover change in mountain regions, which impacts the mountain water cycle and the management and flow of rivers originating in mountain regions.

3. **Variability and trends of water availability:**

How do water & land use and climate change affect the variability (including extremes) of the regional and continental water cycle?

GWF

- GWF's core is the coupled water and energy cycle that is intrinsic to cold regions hydrology. As climate warms, there is further decoupling of snow and hydrological regimes, resulting in increased variability in streamflow.

ANDEX

- ANDEX has updated the estimate of the spatial variability of the human population in the Andes in relation to watersheds and glaciers for the seven countries of the Andean region.

TEAMx

- This topic will be explored within the Mountain Climate Working Group.

INARCH-II

- The coupled water and energy cycle is the core of INARCH. As climate warms, there is further decoupling of snow and hydrological regimes, resulting in increased variability in streamflow.

GPCC

In the course of climate change, variability of extreme precipitation is expected to increase:

- droughts as well as flooding events are expected to increase with climate change.
- An integrated view on global water resources required, as is high resolution precipitation monitoring on a global scale.

Other Key Science Questions

List 1 – 3 suggestion that you anticipate your community would want to tackle in the next 5-10 years within the context of a land-atmosphere project

GWF

- How will extreme atmospheric events and other changes to the climate system be translated by the hydrological system into hydrological extremes?
- How will hydrological storage in lakes, managed reservoirs, glaciers, permafrost, groundwater and wetlands interact with a changing climate and shifting terrestrial ecosystems to create new hydrological regimes?
- How can humans better manage, mitigate and adapt to this change and conserve ecosystems through water and land management, prediction and governance?

ANDEX

- What are the dynamical feedbacks between the Andes and the hydrologic cycle (water vapor, precipitation, evapotranspiration, sublimation, soil moisture, infiltration, groundwater and river flows) at a wide range of spatial and temporal scales, for average and extreme conditions?
- How does the dynamical coupling between water and energy budget change in relation to the current and future changes in climate and land use/land change?
- What is the influence of the cryosphere on the surface hydrologic cycle of the Andes, and what is the influence of the atmospheric hydrologic cycle on the Andean cryosphere?

- How can the presence and management of vegetation directly impact water availability, quality and the overall resilience of water resources in the Andes region?

TEAMx

- One challenge is elevation-dependent climate change, whose quantitative understanding should be improved both through expansion of the (currently very sparse) high-altitude observation network, and through an evaluation of how climate projections for mountain areas depend on the resolution of climate models (especially by analyzing products from convection-permitting climate modeling). Elevation-dependent climate change is thought to be the consequence of feedback processes firmly rooted in near-surface exchange processes (e.g., snow-albedo feedback, cloud-radiation feedback).
- Both mountain weather and climate communities will have to systematically assess the quality of forecast products in mountainous areas compared to their quality in non-mountainous areas. There seems to be agreement that observations generally suffer from non-representativity, while model output is often prone to greater uncertainty. These statements need numerical support.

INARCH-II

- See INARCH-II Science Plan – phase II.

Floods

- What changes in atmospheric and landscape systems control spatiotemporal variability of flooding?
- What is the likely interplay of climate and catchment physical changes (indicators of abrupt system shifts) on flood occurrence and predictability?
- What physical and hydrological factors dominate flood generation mechanisms across scales? And how might this be different in the combined flood generation mechanisms across coastal, urban and rural settings?
- How do changes in the climate system and land system (e.g., dam-induced land use changes, etc.) co-evolve and cascade from atmosphere to land surface and affect catchment susceptibility to flooding? How does the sensitivity and uncertainty of flood simulations increase under non-stationarity?

Contributions to WCRP including the WCRP Light House Activities

Briefly list any specific areas of your panel's activities in particular to the WCRP Light House Activities (Digital Earth, Explaining and Predicting Earth System Change, My Climate Risk, Safe Landing Cimates and WCRP Academy) https://www.wcrp-climate.org/lha-overview.

GWF

- GWF's science goals are directly aligned with the Light House Activity "Explaining and Predicting Earth System Change" and its overarching objective to design, and take major steps toward delivery of, an integrated capability for quantitative observation, explanation, early warning and prediction of Earth System changes on global and regional scales, with a focus on multi-annual to decadal timescales. GWF's focus is on cold regions and high mountain regions as headwaters for major river systems of the world.

ANDEX

- Exchanges between ANDEX and the My Climate Risk Buenos Aires Hub have been initiated and are ongoing. Discussions are currently taking place toward creating a new Hub in Peru (December 2023). Coordination is ongoing with RIfS International Project Office to organize a dedicated activity during the annual meeting of ANDEX in Lima.

AsiaPEX

- To complement the requirement to contribute to the LHA, specific managements under the core group of AsiaPEX are needed. Such strategies are summarized in the science plan.

H_2US

- The RHP H_2US are in dialogue (occasional) with the Digital Earth and Global Precipitation Experiment Lighthouse Activities.

Floods

- The WCRP Light House activities will be discussed and incorporated into the initiative as we move forward with the proposed activities.

TEAMx

- TEAMx research specifically addresses exchange processes over mountains (including evapotranspiration and precipitation). Mountains occupy up to about 50% of the total land area, are home to 1.1 billion people and provide freshwater supplies to about half of humanity. Linking the improved understanding and model capability with applications and climate services is a core part of TEAMx in line with the Light House Activities "Explaining and Predicting Earth System Change" and "My Climate Risk". The TEAMx Programme and Applications webinar held in May 2020 included contributions on hydrology, avalanche warning, aviation meteorology, urban air quality and renewable energy, among others, and several of the presentations at the Second TEAMx Workshop were on applied topics (such as wind energy, air quality, ecology and hydrology).
- From the Safe Landing Climates activity, high-risk events, water resources and the carbon cycle are all topics that are especially relevant in mountain regions and will be investigated in TEAMx. High-impact weather events such as flash floods, landslides, avalanches, air quality events, downslope windstorms, and convective storms are especially relevant in mountainous areas. TEAMx will conduct targeted research into specific physical processes relevant to extreme weather to understand how predictive capability is currently limited and develop improved parameterizations.
- In line with the WCRP Academy goals, TEAMx is an international effort bringing together (to date) 36 project partners (including universities, research institutes and weather services) from 10 countries and over 320 scientists from 20 countries interested in mountain meteorology and mountain climate.
- Early-career scientists are well represented in TEAMx projects and the TEAMx working groups are led mainly by early-to-mid career scientists. Several of the recorded science presentations at the Second TEAMx Workshop were given by Ph.D. students.

Cooperation with other WCRP Projects, Outside Bodies and links to applications
e.g. CLIVAR, CliC, SPARC, Future Earth, etc.

GWF

- GWF has active and productive collaboration and linkage with UNESCO and WMO. GWF has joined the Water and Climate Coalition (WCC; https://www.water-climate-coalition.org/), a community of multi-sectoral actors guided by high-level leadership and focused on water action, intent on effectively addressing both water and climate challenges.
- Three GWF researchers are Chairholders of the UNESCO Chair in Mountain Water Sustainability (https://research.ucalgary.ca/unesco-chair-mountain-watersustainability).
- GWF has helped to propose and initiate the UN International Year for Glaciers' Preservation, 2025.

Baltic Earth

- A collaboration is organized with the Marginal Seas initiative of the Digital Deep Earth (DDE) through a joint international conference “Marine Geology: Marginal Seas - Past and Future”.

ANDEX

- ANDEX has close ties with the Regional Association III (RA III) and the Snow Watch of the Global Cryosphere Watch (GCW) programs of the WMO. ANDEX members are part of the CLIVAR/GEWEX Monsoons Panel. ANDEX is also linked with the CliC and the INARCH-II programs.

AsiaPEX

- For AsiaPEX, GPEX shall be a promising and important collaboration partner in the future. We shall discuss the interaction with GPEX using the GEWEX OSC in July 2024. Integration part of the AMY-II strategy may work with GPEX.
- AsiaPEX collaboration with many Asian projects including TPE, Years of the Maritime Continent (YMC), SAMA, Monsoon Mission, and operational agencies in each country should be strengthened through a suitable membership mechanism of AsiaPEX.

TEAMx

- A CORDEX Flagship Pilot Study (FPS) on high-resolution simulations of mountain climate is being prepared within TEAMx. This is envisaged as a follow-up of two existing FPS (one on convective phenomena over Europe/Mediterranean Sea, the other on the Third Pole Environment). Connections with the INARCH-II cross cut project and with the COnstraining ORographic Drag Effects (COORDE) project (a GASS activity on orographic wave drag) are being further developed.

INARCH-II

- INARCH-II leads a working group under Future Earth - the Climate Impacts on Global Mountain Water Security working group of the Future Earth, Sustainable Water Futures Programme (SWFP).
- INARCH-II contributes to UNESCO Intergovernmental Hydrological Programme (IHP) efforts on climate change impacts on snow, glacier and water resources within the framework IHP-IX (2022–2029), “Science for a Water Secure World in a Changing Environment”.
- Several INARCH-II members are now co-chair holders of the UNESCO Chair in Mountain Water Sustainability.
- INARCH-II co-chaired the WMO High Mountain Summit and is contributing to addressing its call for action, in particular, the observation and prediction aspects of the Integrated High Mountain Observation, Prediction and Services Initiative. It will be imperative for INARCH-II to show leadership and provide guidance for governments to implement this.
- The Global Water Futures (GWF) Program is an expanded follow-on initiative from CCRN. As GWF ends, it will transition to GWF Observatories, maintaining key instrumented observation sites, deployable systems and water laboratories. INARCH-II strongly links with the mountain research components of GWF and GWFO.
- INARCH-II contributes to the UN invitation for “activities aimed at raising awareness of the importance of glaciers, snow, and ice in the climate system and the hydrological cycle….and to share best practices and knowledge in this regard”. The results of COPE will be available for release in 2025 and will be a contribution to this Year.

GRDC

- CLiC — Maintaining the Arctic Runoff Database (ARDB)
- Arctic- Hydrological Cycle Observing System (HYCOS) – Maintaining the Arctic-HYCOS quality assured river discharge dataset

- UNESCO IHP Flow Regimes From International Experimental and Network Data (FRIEND)-Water – Integration of river discharge database from various FRIEND-Water Programmes into the GRDC database. Negotiations ongoing
- Global Climate Observing System (GCOS) – Maintaining and expanding the Global Terrestrial Network for River Discharge (GTN-R) as a baseline network in support of GCOS, United Nations Framework Convention on Climate Change (UNFCCC), GTN-Hydrology and Group on Earth Observations (GEO)
- Former WMO Commission for Hydrology (CHy) – Maintaining and expanding the river discharge data for WMO-defined "Climate Sensitive Stations"
- Support WMO Global Hydrological Status and Outlook System (HydroSOS) activities with data and technical expertise
- Support WMO Hydrological Observing System (WHOS) activities
- Support and provide basis for WMO State of Global Water resources Report 2023

Workshops and Meetings

List of Workshops and Meetings Held in 2023
Meeting title, dates and location.

GWF
- Indigenous Community Gathering, Mistawasis, SK, Canada, 12–14 April 2023 (https://gwf.usask.ca/indigenization/water-gathering-statement.php)
- GWF Finale Open Science Conference, Saskatoon, SK, Canada, 15–17 May 2023 (https://gwf.usask.ca/gwf2023/index.php)

Baltic Earth
- Winter term 2022/2023 (October 2022–January 2023): International master course on "Climate of the Earth System", Rostock University (lectures, exercises, project work, six European Credit Transfer and Accumulation System (ECTS) credits in total, four lecture hours per week, hybrid format)
- 4th International Baltic Earth Winter School for Young Scientists on "Earth System Science for the Baltic Sea Region", Warnemünde, Germany, 27–31 March 2023
- Baltic Sea Science Congress 2023, Helsinki, Finland, 21–25 August 2023
- 9th International Baltic Earth Summer School, Askö, Sweden, 21–28 August 2023
- Baltic-Earth was Co-Convener of the session D1 "CORDEX-Ocean: Towards a CORDEX framework for Ocean Regional Climate Modelling" at the International Conference on Regional Climate (ICRC)-CORDEX Conference, Trieste, Italy, 23–29 September 2023
- International Online Conference "Marine Geology: Marginal Seas - Past and Future", 28–30 November 2023
- Winter term 2023/2024 (October 2023–January 2024): International master course on "Climate of the Earth System", Rostock University

AsiaPEX
- Symposium held in the spring meeting of the Meteorological Society of Japan, 20 May 2023
- Workshop on land-atmosphere coupling
- *The Third Pole Environment and high mountains of central Asia - Hydrometeorological processes and human dimension*, session HS03 in Asia Oceania Geosciences Society 2023 (AOGS2023), Singapore, 1 August 2023

Central Asia

- The Central Asia initiative had an in-person workshop called “Climate Change, Water Resources and Agriculture in Central Asia” (https://www.gewexevents.org/meetings/water-resources- central-asia/), 17–19 May 2023 at the National Research University Tashkent Institute of Irrigation and Agricultural Mechanization Engineers of Uzbekistan (NRU TIIAME), Tashkent, Uzbekistan. The workshop was organized through collaboration between GEWEX/George Mason University (USA), Wageningen Metropolitan Food Clusters/Wageningen University and Research (The Netherlands) and the Central Asia and South Caucasus consortium.

TEAMx

- A two-day hybrid TEAMx Workshop was held in June 2023 in Zürich, Switzerland. The third TEAMx workshop was held on 15–16 June 2023 at ETH Zürich (Switzerland). Around 60 participants attended in-person and 50 more online. The first version of the Numerical Modelling Plan and the first draft of the Implementation Plan were discussed. Besides the workshop activities, the Science Advisory Board convened, and the Coordination and Implementation Group held a meeting. An Online Community Meeting was held on 19 January 2023. The meeting served to update everyone interested in TEAMx on the latest developments and provided a platform for new members to present project ideas.

INARCH-II

- INARCH-II Workshop, Stanley, Idaho, USA, 9–11 October 2023. See: https://inarch.usask.ca/news-events/inarch-workshop-2023.php and the article in the February 2024 issue of *GEWEX Quarterly*: https://www.gewex.org/resources/gewex-news/

Floods

- Flood CC initiative was presented at the 9th International Conference on Flood Management (organized by WMO and UNESCO), Tsukuba, Japan, 18–22 February 2023 (van Oevelen presented the talk on behalf of the team)
- The first Flood CC Workshop will be held virtually on 22 September 2023
- AGU Session December 2023

PannEx

- 11th Seminar for Homogenization and Quality Control in Climatological Databases and 6th Interpolation Conference jointly organized with the 14th European Meteorological Network (EUMETNET) Data Management Workshop, held at the Hungarian Meteorological Service, Budapest, Hungary, 9–11 May 2023
- International conference on hydro-climate extremes and society, held in the University of Novi Sad, Serbia, 27–30 June 2023
- First international scientific conference titled “Agricultural Challenges to Climate Change”, it focused on the role and status of modern agriculture - innovative and sustainable approaches, held in Osijek, Croatia, 19–22 September 2023
- A further meeting was organized as a side event to European Meteorological Society 2023 (EMS2023) Annual Meeting (Bratislava, Slovakia, 3–8 September 2023), CA20108 FAIRNESS WG2, Convener: Branislava Lalic

GPCC

- GPCC colloquium “Global Precipitation Data Sets and their Applications – Status Quo and Way Forward” and workshop at DWD, Offenbach, Germany, 11–12 July 2023
- 3rd Water Data Workshop of the International Centre for Water Resources and Global Change (ICWRGC), Almaty, Kazakhstan, 17–18 October 2023

- 11th Seminar for Homogenization and Quality Control in Climatological Databases and 6th Interpolation Conference jointly organized with the 14th EUMETNET Data Management Workshop, Budapest, Hungary, 9–11 May 2023
- 2023 GHP Meeting, Maynooth, Ireland, 5–7 July 2023
- WMO State of the Climate "Write-Shop", Geneva, Switzerland, 8–10 November 2023

GRDC
- Tag der Hydrologie 2023, Bochum, Germany, May 2023
- EGU2023, Vienna, Austria, April 2023
- International Union of Geodesy and Geophysics (IUGG2023), Berlin, Germany, July 2023
- World's Large Rivers Conference 2023, Vienna, Austria, August 2023
- KISTERS Event, Water Information System from KISTERS (WISKI) User Conference, August 2023
- Central Asia Data Workshop, Almaty, Kazakhstan, October 2023
- International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE) Steering Committee Meeting, November 2023
- HYDROSPACE2023, Lisbon, Portugal, November 2023

List of Workshops and Meetings Planned in 2024 and 2025
Meeting title, dates and location and anticipated travel support needs

GWF
- Canadian Water Resources Association Conference, Saskatoon, SK, Canada, June 2024 (https://conference.cwra.org/)
- AGU Water Science Conference, June 2024, Saint Paul, MN, USA (https://www.agu.org/waterscicon)

Baltic Earth
- 5th International Baltic Earth Winter School for Young Scientists on "Earth System Science for the Baltic Sea Region", Sopot, Poland, 18–22 March 2024
- Baltic Earth Session at EGU 2024: "Human and other drivers of change: Impacts and interlinkages in marginal seas and their coastal regions", Vienna, Austria, 14–19 April 2024 (merged with two other sessions. Now joint session: "Interdisciplinary approaches to understanding processes in coastal regions and nature-based solutions",https://meetingorganizer.copernicus.org/EGU24/session/50355)
- 5th Baltic Earth Conference, Latvia, 13–17 May 2024
- 9th GEWEX Open Science Conference, Sapporo, Japan, 7–12 July
- 10th International Baltic Earth Summer School, Askö, Sweden, 26 August–2 September 2024
- 2nd Baltic Earth Workshop on Multiple Drivers, Hamburg or Helsinki, autumn/winter 2024
- Winter term 2024/2025 (October 2024–January 2025)

ANDEX
- ANDEX Annual Meeting, Peru, 26 May–1 June 2024

TPE-WS
- TPE-WS: Very active in EGU, AGU and AOGS planned for 2024

H_2US

- The RHP H_2US expects to host 1–2 planning workshops in 2024 and 2025 (dates, venues TBD). They envision needing travel support for approximately 14 members of their implementation steering group.

AsiaPEX

- Workshop on adaptation to climate change, 14–15 March 2024
- 1st Workshop on Mega-Geo-Hazards under Changing Climate, Akama Hotel, Kathmandu, Nepal, 14–15 March 2024
- Session in the GEWEX Open Science Conference (GEWEX OSC), Sapporo, Japan, 7–12 July 2024: Observational and Modeling Initiatives for the Asian Monsoon Field Campaign (AsiaPEX and AMY-II). The AsiaPEX meeting will be held during this OSC

Central Asia

- The Central Asia initiative is planning for an in-person workshop, "Better Data, Modeling & Planning for Climate Adaptation in Central Asia" to be held Osh State University, Osh, Kyrgyzstan from 29 April–1 May 2024

TEAMx

- At EMS (2–6 September 2024, in Barcelona, Spain), there will be a session on "Transport and Exchange Processes in the Atmosphere over Mountains". Furthermore, a side meeting dedicated to TEAMx will be held.
- In November 2024, the fourth TEAMx Workshop will be held as a hybrid meeting in Innsbruck.

INARCH-II

- INARCH-II Workshop, Lanzhou and Zhangye, China, 14–19 October 2024, https://inarch.usask.ca/news-events/inarch-workshop-2024.php

PannEx

- Training school on micrometeorological measurements and applications and the 7th PannEx Workshop is organized in Budapest, Hungary, 10–14 June 2024

GPCC

- EGU General Assembly, Vienna, Austria, 14–19 April 2024
- EMS Annual Meeting, Barcelona, Spain, 2–6 September 2024

GRDC

- Brainstorming meeting for State of Global Water Resources Report 2023, Geneva, January 2024
- EGU2024, Vienna, April 2024
- 5th Baltic Earth Conference, Jurmala, May 2024
- 9th GEWEX OSC, Sapporo, July 2024

Other Meetings Attended On Behalf of GEWEX or Panel in 2023

GWF

- WMO Oslo Meeting, March 2023
- UN Water Conference, March 2023
- Proposal for United Nations (UN) International Year for Glacier's Preservation 2025: Pomeroy was asked to present the keynote talk on the International Year at a session hosted by the President of Tajikistan, King of the Netherlands, President of Bolivia, Secretary General of the United Nations, Secretary-General of WMO, Head of UNESCO

and other organizations [World Bank, World Economic Forum, International Atomic Energy Agency (IAEA)] at the UN Water Conference at UN Headquarters in March 2023.

AsiaPEX

- "Multiple perspectives on Asian summer monsoon research" symposium in the spring general meeting of the Meteorological Society of Japan, 20 May 2023, Tokyo, Japan (in Japanese)

INARCH-II

- INARCH-II represented global academia at the World Meteorological Organization's Commission for Observation, Infrastructure and Information Systems (INFCOM) Workshop on Coupling of Cryosphere in Numerical and Earth System Models and First Meeting of the Global Cryosphere Watch Advisory Group in Oslo, Norway in March 2023. INARCH's advances in cold regions modeling were highlighted and recommendations were included in WMO's new plans for snow and hydrology services to member states.
- A joint GWF & INARCH-II proposal for an international year for snow and ice developed into a resolution to the UN General Assembly from Tajikistan for 2025 to be the International Year for Glaciers' Preservation and each March 20th to be International Glacier Day.
- TEWEX Clima Conference, Shangri-La, China, 7–10 August 2023. M. Brody presented the plans for this initiative and consulted with a wider TPE community as well as represented IGPO during this meeting.

Publications during Reporting Period

List of Key Publications

See individual reports for a complete list of publications by each activity.

2.3.1. GHP Rapporteurs Report

Panel: GEWEX Hydroclimatology Panel
Rapporteur(s): Qingyun Duan, Li Jia

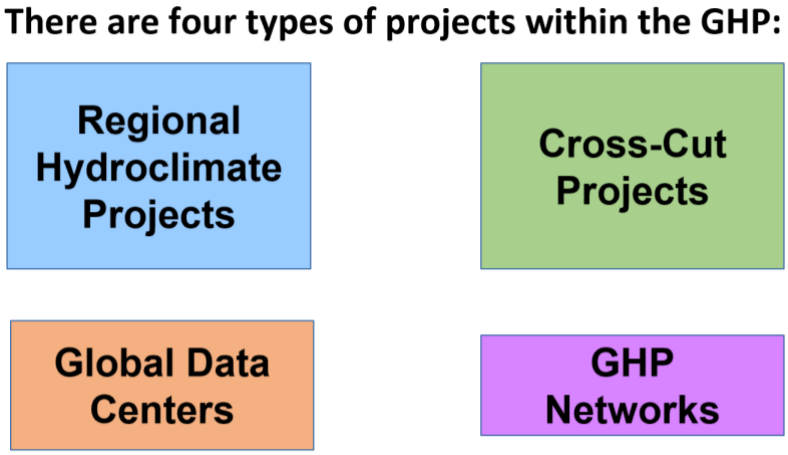
Adherence to GEWEX and Panel's objective(s)

The overall GEWEX goals and GHP goals are consistent. The GHP goal is as follows:

- To understand and predict continental to local-scale hydroclimates for hydrologic applications by concentrating on improving our understanding of environmental water and energy exchanges at the regional scale to form an integrated perspective.

Achievement of annual goals for this reporting period

- An energetic Panel with Ali Nazemi and Paola Arias as co-chairs and a panel of 12 members which is diverse in terms of career stages, genders and geography.



- Regional Hydroclimate Projects (RHPs) aim at understanding and predicting hydroclimatology in a specific region. Two RHPs are formerly started, four have taken off in 2022–2023, and one new prospective RHP (Central Asia Initiative) is under preparation. The six active RHPs are:
- Global Water Futures
- Baltic Earth
- TPE-WS (Third Pole Environment-Water Sustainability),
- AsiaPEX (Asian Precipitation Experiment)
- H_2US (Humans and Hydroclimate in the United States)
- AndEX (Regional Hydrology Program for the Andes)
- + 1 prosspective RHP (Central Asia Initiative)
- Cross-Cut (CC) Projects are designed to focus on specific physical processes and topics, creating collaborations between RHPs, other GEWEX Panels and WCRP activities. One of the prospective CCs is seeking active leadership. The three active CCs are:
- TEAMx (Transport and Exchange Processes in the Atmosphere over Mountains Experiment): to improve the current understanding of exchange processes in the atmosphere over mountains and how these processes are parameterized in climate models

- INARCH-II (2nd phase of International Network for Alpine Research Catchment Hydrology): to better understand alpine cold regions hydrological processes, improve their prediction and find consistent measurement strategies
- d-ET (Determining Evapotranspiration): focuses on methods allowing us to determine evapotranspiration (ET), experimentally, through remote sensing methods or via models, at different spatial and temporal scales (no report for 2023)
- The 4 prospective CCs are:
- Flood CC: aims to propagate flood modeling and research knowledge from one region to the other and synthesize results globally
- Surface Water CC: former HYDROLARE CC, which focuses on advancing global surface water science for local benefits
- Groundwater CC: will hold a workshop during OSC; likely to emerge in the coming years
- MOUNTerrain CC (Precipitation over Mountainous Terrains): focuses on precipitation over mountainous terrain (seeking active leadership)
- Data centers aim at collecting and distributing hydrologically-relevant data. The two data centers are:
- GPCC (Global Precipitation Climatology Centre): new leadership coming
- GRDC (Global Runoff Data Centre): new leadership coming
- GHP Networks maintain collaboration and capacity building activities relevant to GEWEX science. The active GHP network is:
- PannEx: a network over the Pannonian Basin, which has been successful at engaging the community
- Excellent geographical coverage, except African and Mid-Eastern arid regions
- Strong links to other WCRP core projects and Lighthouse Activities, such as CLIVAR, CliC, My Climate Risk, Safe Landing, Digital Earth, and with other programs including WWRP, CMIP6 and Future Earth.
- Strong collaborations with other GEWEX Panels such as GASS, GDAP and GLASS
- The Panel has infused a lot of new blood with a robust membership structure (four senior researchers, seven mid-career researchers and three ECRs).
- Established new operating guidelines for members and activities

Arisen or noted science issues

- What are the best ways to model and predict integrated natural and socio-economic processes and inform decision processes?
- How to address uncertainties?
- Consider not only just water-related processes such as floods and droughts, but also energy, biogeochemical processes and interactions among atmosphere, hydrosphere, biosphere and anthropocene, with emphasis on societal impacts.

Emerging Science

- How to consider AI, ML and Digital Twins tchnologies?

Future plans

- Six active RHPs are ongoing (Baltic Earth, ANDEX, GWF, TPE-WS, AsiaPEX, H2US) and one new RHPs is under preparation (Central Asia).

- Three Crosscutting Activities are ongoing (TEAMx, INARCH), and four new Crosscutting Activities are being started.

Recommendations to Panel

- Even more interactions and integration among RHPs and CCs are desirable:
- can different process-based CCs be combined or some strong collaboration be established? (e.g., ET CC, Flood CC and/or Groundwater CC?)
- How can mountain-related RHPs (ANDEX, INARCH, TPE-WS…) be coordinated so as not to reinvent the wheel?
- Even more collaboration between Panels:
- Process-based RHPs and CCs and GLASS projects on land surface modeling (e.g., SoilWAT, Irrigation CC, ET CC, etc.)
- Collaboration between GHP data centers/networks and GDAP
- Under-represented regions:
- Africa is a glaring miss. Can we start a monsoon RHP in Africa? How about a water-food-climate nexus RHP or CC?
- Involve more communities outside GEWEX [e.g., the Hydrologic Ensemble Prediction EXperiment (HEPEX), Global Flood Partnership, etc.]
- Reshape the d-ET CC: propose to re-organize it by involving more scientists to cover broader issues from Europe, USA, China and other places.

Considerations for SSG

- A lot of projects are ongoing or being started. Some have been going on for a long time. What lessons can we draw from them before we start new ones? How about creating some legacy deliverables by documenting them in journals?

Additional Remarks

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2.4. Global Land/Atmosphere System Study Panel (GLASS)

Full Panel Name (Acronym) : Global Land/Atmosphere System Study Panel
Reporting Period : 01 January - 31 December 2023
Starting Date : ….
End Date (where appropriate): N/A
URL : https://www.gewex.org/panels/global-landatmosphere-system-study-panel/

Membership

Chair(s) and Term Dates : Kirsten Findell, 2019 – 2023
Anne Verhoef, 2020 – Present
*Nathaniel Chaney, 2024 – Present

Members and Term Dates : *Gab Abramowitz, 2008 – Present
Souhail Boussetta, 2018 – Present
Laura Condon, 2022 – Present
^John Edwards, 2014 – Present
Marina Hirota, 2023 – Present
*Hyungjun Kim, 2010 – Present
*David Lawrence, 2014 – Present
*Patricia Lawston-Parker, 2022 – Present
^Xianhong Meng, 2019 – Present
Vimal Mishra, 2023 – Present
^Joshua Roundy, 2016 – Present
*Joseph Santanello, 2011 – Present
Gert-Jan Steeneveld, 2021 – Present
Asaminew Teshome Game, 2023 – Present
*Volker Wulfmeyer, 2020 – Present
*Yijian Zeng, 2020 – Present
^Yunyan Zhang, 2021 – Present
** GLASS project lead*
^ GLASS Liaison to relevant initiative

Panel Objectives, Goals and Accomplishments during Reporting Period

Overall Panel Objective(s)

- Encouragement of land modeling developments by coordinating the evaluation and intercomparison of the new generation of land models and their applications to scientific queries of broad interest, including the proper representation of land-atmosphere interactions with focus on the role of land.
- To develop novel ways to evaluate experiments to address the central question, “Does my land model describe the processes in the climate system sufficiently well?”

List of Panel Goals

Adjust yearly

- Leveraging recent novel developments, i.e., on Machine Learning techniques, and comprehensive 4-D in situ and remotely-sensed observations of the Earth’s critical zone*, and atmospheric states, to:

- Improve understanding and representation of mechanistic processes in land models, especially over heterogeneous surfaces, with a focus on turbulence parameterizations (including Monin–Obukhov Similarity Theory, or MOST), surface flux partitioning, as well as vegetation and soil processes
- Further improve and develop cutting-edge metrics and methods to confront land model performance subsurface-soil-vegetation-atmosphere system

List of 2 to 3 Key Results
Adjust yearly with respect to goals

- **Protocol for the Analysis of Land Surface models (PALS) Model Benchmarking Evaluation Project, Phase 2 (PLUMBER2)**: Refinements and improvements compared to the original PLUMBER experiment revealed that when land surface models (LSMs) are worse than the empirical model suite, they are often much worse, which causes a poor comparison overall against empirical benchmarks. No LSM can outperform an out-of-sample linear regression prediction of fluxes, with instantaneous SWdown as the **only** predictor
- Deutscher Wetterdienst Meteorologisches Meteorological Observatory at Lindenberg (DWD MOL) in Lindenberg, Germany, and Ruisdael Observatory in the Netherlands became **GLAFOs**; new GLAFOs are under discussion/in preparation in Brazil and Ghana
- **Coupling of Land and Atmospheric Subgrid Parameterizations (CLASP) Project**: A model sensitivity analysis using the HydroBlocks model illustrates the role turbulence parameterizations can have on the temporal persistence of simulated land surface temperature (LST); secondary circulations that are seen to develop in the LES experiments due to surface thermal heterogeneity over the Southern Great Plains site can be qualitatively reproduced in a two-column model that interacts via a parameterized circulation; to provide more conclusive evidence regarding the role of surface thermal heterogeneity on the macroscale atmospheric response, a series of 3 km WRF experiments were run over the Contiguous United States over the summers of 2021–2023
- **Solar Induced Fluorescence Model Intercomparison Project (SIF-MIP)**: Model output submitted from three modeling groups and three tower sites, based on reanalysis forcing. Tower observed SIF output has been formatted and made publicly available with DOIs. Initial results show significant spread in estimated carbon and water exchange. Much work is needed to ensure modeling teams are following protocol, as is always an issue with MIPs

Other Science Highlights
Not part of the 2-3 key results

- First **PLUMBER2** paper is submitted and is in review. Preprint is here: https://egusphere.copernicus.org/preprints/2024/egusphere-2023-3084/
- Patricia Lawston-Parker (**Irrigation CC**) convened a special issue focused on the use of Earth observations for understanding irrigation and its impact on the climate system
- **The Local Land-Atmosphere Coupling (LoCo) Working Group** continues to influence local coupling components and aspects of field campaigns [Land-Atmosphere Feedback Experiment (LAFE)/Land-Atmosphere Feedback Observatory (LAFO)/GLAFO, Great Plains Irrigation Experiment (GRAINEX), Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) campaign, ARM Third Mobile Facility (AMF3)]. They also explored coordinated expansion of LoCo scope via collaborative proposals, AGU/AMS sessions, and experiments
- Steady progress on soil parameterizations via the **GEWEX Soil and Water Initiative** (**SoilWat)** project and relating review and science papers, e.g., on combining root and soil hydraulics in macroscopic representations of root water uptake

- **GLAFO** is pioneering new approaches to measure atmospheric surface layer profiles using a synergy of scanning remote sensing in combination with tower measurements; GLAFO is also developing new methods for the evaluation of these observations using similarity-theory and machine-learning approaches to improve the parameterization of surface fluxes
- With **CLASP** evolving towards numerical weather prediction spatial scales, there is a growing recognition that future focuses of CLASP should revolve around how surface heterogeneity impacts turbulence and mean advection at the surface and thus its impacts on surface fluxes which remains a persistent weakness in LSMs. The role of microscale circulations and how moisture and heat are transferred between sub-grid units is seen as the next frontier of future CLASP efforts.

Panel Activities during Reporting Period

List of Panel Activities and Main Result

SoilWat

- A range of thermal regime analyses are steadily progressing. For example, collaborations with Frederic Vitart (ECMWF) on analyzing the S2S outputs to understand the difference in the thermal regime represented by various ESMs, and how such differences impact the land-atmosphere interactions, are taking place. This activity is linked with LS4P led by Yongkang Xue; the Soil Parameter Model Intercomparison Project (SP-MIP) results have been analyzed further and will be tied in with the S2S analyses.
- The white paper on “Soil Thermal Properties” has gone through another round of revisions and the near- final draft version is in preparation.

CLASP

- **CLASP** project meeting in Princeton, NJ in May, 2023—First in-person project meeting that brought together the full CLASP team as well as other boundary layer scientists within the US

SIF-MIP

- Wrote *GEWEX Quarterly* article on SIF-MIP
- SIF-MIP leadership team met several times with modelers to discuss protocol and modeling activities

Irrigation CC

- Members (led by Lawston-Parker) led a special issue in the Elsevier journal *Agricultural Water Management* on “Irrigation monitoring through Earth Observation (EO) data”. The special issue accepted papers from 1 Sept 2023 to 29 Feb 2024.
- Members participated in an Aspen Global Change Institute (AGCI) workshop on Irrigation in the Earth System held in Aspen, Colorado in June 2023. Outcomes from the meeting include i) a list of irrigation ideas/paper titles/proposal ideas that will be followed up on by attendees and others and ii) a list of irrigation datasets and sources.

ET CC

- The LIAISE workshop took place in Lleida between 27–29 March 2023, with various GLASS members and liaisons presenting and attending. The LIAISE project aims to improve the understanding of land-atmosphere-hydrology interactions in a semi-arid region characterized by strong surface heterogeneity owing to contrasts between the natural landscape and intensive agriculture.

LoCo

Some highlights examples below (more in Loco report):

- Operational Center Engagement

- Findell et al. (2024) GMD paper focused on guidance for operational GCM centers output variable and temporal/vertical resolution requirements for LoCo metric applications.
- Planetary Boundary Layer (PBL) Observing System & NASA PBL Incubation
  - NASA PBL Study Team (including GLASS members Santanello and Wulfmeyer) delivered a white paper to NASA Headquarters on the vision for a PBL Observing System and NASA PBL Incubation activities (technology, models, science) over the next decade. Includes Science and Applications Traceability Matrix (SATM) for land-atmosphere science that includes LoCo.
- Field campaigns & associated LoCo activities
  - LAFE/GLAFO science: Wakefield et al. and LoCo metrics (paper and AMS talk) using LAFE datasets
  - LIAISE campaign: LoCo and irrigation metric applications by United Kingdom Meteorological Office (UKMO), MIPs (2023 workshop)
- LoCo science scope expansion (community involvement and influence)
  - NASA Soil Moisture Active Passive (SMAP) and Modeling, Analysis, and Prediction (MAP) Projects—9 current projects funded relevant to LoCo/GLASS; new SMAP/MAP solicitations in ’23 and at least six proposals submitted from LoCo interests
  - NASA S2S Hydromet (March 2022)—FIve proposals from LoCo WG members; two selected
  - AGU and AMS sessions (23)—L-A session convened by LoCo WG members
  - New member: Eunkyo Seo

PLUMBER
- First PLUMBER2 paper submitted, as noted above

GLAFO
- Extension of GLAFO White Paper
- Combination of GLAFO with a new Atmospheric Boundary Layer Study (GABLS)
- DWD MOL in Lindenberg, Germany, and Ruisdael Observatory in the Netherlands became GLAFOs
- New GLAFOs in preparation in Brazil and Ghana
- ARM site in the US requested to become GLAFOs
- Collaboration with AmeriFlux
- Collaboration with CLASP

List of New Projects and Activities in Place and Main Objective(s)

We started a number of new projects in recent years, so 2023 was a year for consolidation, and therefore no new projects were set up as such, but various between-project collaborations were established.

GLAFO-GABLS-LoCo
- A new GABLS is in preparation oriented around LAFO and the ARM Southern Great Plains (SGP) site. The unique observations at these sites will provide the verification of a simulations with land-atmosphere model systems such as the UK Met Office Unified Model, ICOsahedral Non-hydrostatic-Jena Scheme for Biosphere-Atmosphere Coupling in Hamburg (ICON-JSBACH) model, WRF-NoahMP-Gecros, WRF-NoahMP-Hydro-Iso, and PALM
- The new project Land-Atmosphere Feedback Initiative (LAFI), the Collaborative Research Unit (RU) 5639 of the German Research Foundation (DFG), was funded with participants of

more than 10 research institutes in Germany. This project will be strongly interwoven with GLAFO and GLASS activities.

LoCo

- As part of the Field Experiment on submesoscale spatio-temporal variability in Lindenberg (FESSTVaL) campaign (fesstval.de), Chiel van Heerwaarden et al. are setting up simulation cases in which we compare ICON in different configurations and other LES models such as MicroHH. They have a set of shallow cumulus and deep convection cases with many observations taken during the campaign. They are exploring the idea of making it a GEWEX intercomparison, and try to come up with something that is at least sufficiently different than earlier intercomparison and that what LES ARM Symbiotic Simulation and Observation (LASSO) is offering. Some of the DWD and Max Planck Institute people involved. They will probably join the PanGASS to pitch the idea there.

PLUMBER

- Adaptation of PLUMBER2 analyses to an automated model development environment in modelevaluation.org is underway.
- Still actively working with Fluxnet folk (Dario Papale, Martin Jung and others) to automate delivery of flux tower data, with LSM-focused quality control, in ALMA netCDF format, to modelevaluation.org. API is the main roadblock, but development together with Australian Community Climate and Earth System Simulator-National Research Infrastructure (ACCESS-NRI) is underway.

Irrigation-CC

- Various projects are currently underway led by the members of the Irrigation project: Biosphere and Land Use Exchanges with Groundwater and Soils in Earth System Models (BLUEGEM, Principal Investigator: A. Ducharne); Climate Change Initiative – Anthropogenic Water Use (CCI-AWU, funded by EDSA, led by Luca Brocca); CAS-Climate: To Irrigate or Not? Assessing Climate Change Adaptation for Sustainable Water- Agriculture Systems in the Mississippi River Basin (Principal Investigator: Y. Pokhrel)

List of New Projects and Activities Being Planned, including Main Objective(s) and Timeline, Lead(s)

- Souhail Boussetta, with inputs from Gab Abramowitz and others, is in the initial stages of setting up a new project that fits well with the Panel's renewed goals. This concerns **ML4LM**: Machine learning for Land Models
- Laura Condon, together with Stefan Kollet, is in the process of setting up a new initiative that involves a dedicated **GEWEX groundwater activity (a GHP-GLASS cross-cut**). A kick-off workshop will take place at the OSC in Sapporo (https://www.gewexevents.org/meetings/gewex- osc2024/program/groundwater-workshop/).
- The Advancing the Frontiers of Earth System Prediction (AFESP, https://research.reading.ac.uk/earth- system-prediction/) project is led by Anne Verhoef on "Towards a high-fidelity integrated forecasting system via ground-breaking and ambitious data-assimilation of the dynamic soil-vegetation hydraulic continuum". A 5-year funded (University of Reading and ECMWF) collaborative research project has been established between the **SoilWat** leads (Y. Zeng and A. Verhoef) and ECMWF (with GLASS Panel member Souhail Boussetta as one of the co-Investigators).
- **SoilWat** (lead: Zeng) will also be contributing to the GABLS project, in terms of understanding the role of (heterogeneous surface/sub-surface) soil properties on land-atmosphere interactions.
- **The SoilWat** "Soil-Cloud Cascade" sub-project (lead: Zeng) that was initiated with Yunyan Zhang requires some new momentum.

- **Irrigation-CC**: “Leveraging SMAP soil moisture to assess the net impact of irrigation heat extremes” (lead: T. Lawston-Parker). A proposal was submitted to the NASA Research Opportunities in Space and Earth Sciences (ROSES) Soil Moisture Active Passive (SMAP) Science Team solicitation in Aug 2023.
- Propose to use SMAP soil moisture products and NASA models to investigate the net effect of irrigation on moist and dry heatwaves. The outcome of the proposal is still pending. They are also in the process of setting up a website to provide the following to members, potential members, and the public:
- Recordings of past quarterly meetings
- Information about upcoming project meetings
- Resources such as list of collaboration topics, intercomparison output, etc.
- Relevant announcements (e.g., upcoming major conference sessions, proposal deadlines, etc.)
- List of publications that will be updated regularly

Science Issues and Collaboration during Reporting Period

Contributions to Developing GEWEX Science and the GEWEX Imperatives.

a. Data Sets

- A list of irrigation datasets and sources collated by the Irrigation project (see **Irrigation CC** report)
- **GLAFO**: New data sets on the L-A system are available for the LAFO site. Advanced data processing schemes and sophisticated research data management are ongoing, e.g., in collaboration with National Research Data Infrastructure for Earth System Sciences (NDFI4Earth, https://www.nfdi4earth.de). This contains: soil moisture and temperature network; vegetation parameters and variables; canopy profiling; surface layer profiles and fluxes; diurnal cycle of PBL turbulence and fluxes including morning transition and afternoon decay, stable und unstable PBL; high-resolution satellite observations of surface and vegetation variables; unmanned aerial vehicle (UAV) observations of land surface. In the future also isotope measurements and fiber-optical distributed sensors
- **SoilWAt**: Gupta, S., Lehmann, P., Bickel, S., Bonetti, S., & Or, D. (2023). Global mapping of potential and climatic plant-available soil water. *Journal of Advances in Modeling Earth Systems*, 15, e2022MS003277. https://doi.org/10.1029/2022MS003277
- **PLUMBER2**: Team is still actively working with Fluxnet folk (Dario Papale, Martin Jung and others) to automate delivery of flux tower data, with LSM-focused quality control, in ALMA netCDF format, to modelevaluation.org. API is the main roadblock, but development together with ACCESS-NRI is underway.
- **LoCo**: New DOE-ARM PBL height value-added product (VAP) dataset (Damao Zhang and Yunyan Zhang et al.) under development; global PBL height characterization dataset from wind profiler network (Salmun et al.)
- **CLASP**: Development of parametric space-time covariance parameters from geostationary satellites over the Contiguous United States (Conus); these are then leveraged to evaluate simulated space-time persistence in models
- **SIF-MIP**: Worked with Dave Bowling at University of Utah to curate tower flux and met data; worked with Zoe Pierrat at Jet Propulsion Laboratory to curate tower SIF data

b. Analysis

- **PLUMBER2**: For the first time, funding has been secured to actively develop the automated evaluation system in modelevaluation.org, so that trunk-branch evaluation of multiple LSM configurations can be automated. This will start with application of the PLUMBER2 diagnostics and machine-learning based benchmarks. While this is national funding in Australia, other groups have expressed an interest in co-developing the platform, and once the project contracts are signed and everything is underway, this will be coordinated through GLASS.
- **GLAFO**: Data processing and quality control of a synergy of observations such as surface fluxes, surface energy balance closure, and turbulence profiles in the ABL as well as their relations to soil and vegetation parameters and variables. All data will become available in a NetCDF.
- **LoCo**: Continued development of LoCo Cheat Sheets: http://cola.gmu.edu/dirmeyer/Coupling_metrics.html
- **CLASP**: Analysis of the simulated space-time covariance of LST when compared to satellite remote sensing illustrates a persistent poor performance in simulating the observed space-time patterns of LST over large regions of the Contiguous United States. A sensitivity analysis illustrates the role turbulence parameterizations can have on the temporal persistence of simulated LST.

c. Processes

- **GLAFO**: Studies of relations between fluxes, ABL development and soil and vegetation states as well as the effects of heterogeneities. This includes: turbulent transport, entrainment, evapotranspiration, sensible heat flux, ground heat flux, radiation, cloud formation, morning transition and afternoon decay
- **SoilWat**: There is a discussion on how basic soil properties (and pedotransfer functions, or PTFs) impact land-atmosphere interactions. Several meetings were organized (Yunyan Zhang, Min Huang, Yijian Zeng, Anne Verhoef, Bob Su, Ruby Leung). It seems there is an emerging potential to have a working group focusing on process level understanding of cloud physics and soil-water-plant-energy interactions. This is because different soil maps (PTF parameters) will impact the evaporative fraction that is closely linked to shallow cumuli. It noted that this "initiative" should be closely co-coordinated with the LoCo and CLASP projects. We also envisage that it would cut across different Panels (e.g., GASS).

d. Modeling

- In the AFESP project (Principal Investigator: Verhoef), which will be part of the **SoilWat** activity, we will actively engage with the latest theory and modeling of the soil-plant hydraulic system, to work towards an unifying soil hydro-thermal theory that can be used, in conjunction with suitable remote sensing observables, to explore the use of a novel "vegetation as a root-zone soil sensor" (VaaSS) approach for spatio-temporal derivation of subsurface properties.
- The Simultaneous Transfer of Energy, Mass and Momentum in Unsaturated Soil-Soil Canopy Observation, Photochemistry, and Energy Fluxes (STEMMUS-SCOPE) model (Principal Investigator Zeng) runs for **PLUMBER2** sites have completed. It turns out that modelevaluation.org is not only applicable for evaluating LSM performance, but also that the LSM models can also help identify errors in the meta data of the forcing data (e.g., the canopy height and reference height of various sites).
- **GLAFO**: Modeling will be performed in connection with LAFI and **GABLS**, with a focus on: simulation of the land-atmosphere system from meso- down to turbulence-permitting

scales to study scale interaction and scaling laws as well as the effect of micro-scale flow on surface and PBL properties; combination with single-column models and LES with homogeneous surface; mostly multi-nested design under realistic large-scale forcing including data assimilation, which will link nicely to the new **SoilWat** AFESP VaaSS activity.

e. Application

- **SoilWat**: The use of thermal inertia and damping depth derived from LSM bare soil surface temperatures as a soil thermal processes-related metric; the soil temperature climatology can be used as a metric to evaluate the thermal processes in LSMs as well.
- Ultimately **GLAFO** outputs will lead to improved NWP for nowcasting, short- to medium-range and S2S forecasts, as well as advanced km-scale regional climate projections by incorporation of better representation of L-A feedback and vegetation properties.

f. Technology Transfer

- **PLUMBER2**: See analysis above—the **modelvaluation.org** system and the machine learning based benchmarks as a public resource fit a technology transfer
- **GLAFO**: Commercialization of remote sensing systems; operational application of new remote sensing systems at observatories; operational turbulence-permitting forecasting; operation of advanced instrumentation at sites like Brazil and Ghana

g. Capacity Building

- **SoilWAt**: Co-organize Working Group (WG) meetings with International Soil Modelling Consortium (ISMC) Soil Thermal Properties WG, Pedotransfer Function WG, Soil Carbon WG, Soil Math WG for bridging soil processes and Earth system models
- **GLAFO**: Incorporation of GLAFO science in educational BSc and MSc programs; collaboration with forecast centers such as the Royal Netherlands Meteorological Institute (KNMI) and DWD; collaboration with developing countries such as Ethiopia; educational efforts planned at all current and future GLAFO sites (including in Brazil and Ghana) to demonstrate the measurement methodology, operation, maintenance and processing of GLAFO data

List contributions to the GEWEX Science Goals and plans to include these.

Goal # 1 (GS1): Determine the extent to which Earth's water cycle can be predicted. This Goal is framed around making quantitative progress on three related areas posed in terms of the following questions:

1. **Reservoirs:**

What is the rate of expansion of the fast reservoirs (atmosphere and land surfaces), what is its spatial character, what factors determine this and to what extent are these changes predictable?

- **Irrigation CC**: Irrigation modifies natural "fast" reservoirs at the surface (through soil moisture then land-atmosphere interactions) as well as slower reservoirs like surface water (through diversion) and groundwater. Although the irrigation project emphasizes the land-atmosphere component, it is inseparable from considerations of human water management and the social dimension of irrigation water usage.
- **SoilWat**: It is important to include groundwater as a component in ESMs to represent reservoirs better. The Groundwater Initiative led by Stefan Kollet and Laura Condon (GLASS) would be a valuable input.
- To be studied with **GLAFO** long-term measurements

- Inherently, the **LoCo** paradigm and process-chain captures all three elements of GS1 and describes the connections between reservoirs (SM), fluxes (ET), the PBL, and ultimately clouds and precipitation (extremes). As such, Earth's water cycle is comprised of these links and feedbacks and any changes (as posed here) in one will impact the others. LoCo is designed to understand how/why these changes impact the water cycle as a whole, recognizing the interconnectedness inherent in reservoirs, fluxes and precipitation.
- **SIF-MIP** data assimilation experiments will evaluate impacts of SIF and other vegetation constraints on the water pools, including plant available and unavailable water in soils. In the first instance, these experiments will focus on a few towers in high-latitude and high-altitude environments.

2. **Flux exchanges:**

To what extent are the fluxes of water between Earth's main reservoirs changing and can these changes be predicted and if so on what time/space scale?

- As with any component of the Earth system, by definition "changes" can only be predicted and understood by knowing the truth, i.e., via observations. There has been progress in soil moisture and precipitation observations on the global scale from satellite, but surface fluxes and PBL processes remain a significant challenge in routinely monitoring them. These issues are addressed in several GLASS projects, including **LoCo, GLAFO,** etc.
- The **Irrigation CC** includes scientists whose research includes mapping irrigated areas using remote sensing data. Recent advances in tools and computational power have allowed for the creation of annual maps of irrigated areas, which has and will continue to improve our understanding of time-varying changes to irrigation acreage (and therefore SM/surface reservoirs). The irrigation effort also includes members working on the ESA + irrigation project that seeks to estimate irrigation water use from space.
- **SoilWat** is evaluating how PTFs/soil properties/soil process descriptions will impact the water, energy and carbon cycle (at multiple spatiotemporal scales). Ultimately, this will improve predictions of land surface states and fluxes.
- Studies are already ongoing with **GLAFO** surface energy balance measurements and in collaboration with the new GABLS.
- SIF-MIP's data assimilation experiments will evaluate impacts of SIF and other vegetation constraints on the water fluxes including evapotranspiration and runoff. In the first instance, these experiments will focus on a few towers in high-latitude and high-altitude environments.

3. **Precipitation Extremes*:***

How will local rainfall and its extremes change under climate change across the regions of the world?

- **SoilWat**: The improved description of soil processes in LSM/climate models will improve the quantification of flux exchanges, which will inevitably improve the estimation of precipitation extremes. For example, afternoon rain falls preferentially over dry soils, particularly over semi-arid regions, where surface fluxes are sensitive to soil moisture and convective events are frequent.
- **LoCo** metrics cover a wide range in terms of which links in the process chain are the focal points of each, and as such, which observations are needed to compute metrics and apply to prediction models. For example, terrestrial leg metrics (particularly statistical ones) require long record lengths of SM and fluxes, which aren't always available. SM-P feedback metrics require SM and precipitation and thus address changes in each/both simultaneously.
- **CLASP:** Representation of km-scale heterogeneity over the land surface shows a clear impact on model predictability of precipitation as illustrated via surface homogeneous vs heterogeneous WRF experiments over the Contiguous United States.

- **SIF-MIP** modeling protocol currently does not account for land surface feedbacks to the atmosphere, but this is an interesting and important direction for SIF-MIP.

Goal # 2 (GS2): 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:

1. **Forcing-feedback understanding:**

How can we improve the understanding of climate forcings and feedbacks formed by energy, water and carbon exchanges?

- The realistic consideration of soil processes in climate models will help improve the forcing-feedback understanding. **SoilWat** is making various efforts in terms of representing soil processes in climate models; for example: the coupled soil moisture and heat transfer (which is important for arid and semi-arid areas), the soil-root hydraulics (which is important to link soil moisture states with land surface variables and fluxes), the soil-groundwater interaction (which is often neglected in climate model while its importance for affecting land surface flux exchanges is non-trivial).
- **GLAFO** long-term measurements will contribute to the understanding of the L-A feedback chains over the entire regime of soil moisture conditions, vegetation properties and in dependence of large-scale forcing as well as permit studies to quantify the effects of land use and land cover changes (LUCC) on regional weather and climate.
- **SIF-MIP** data assimilation experiments will evaluate impacts of different observational constraints on energy, water and carbon exchanges. Data assimilation systems will look for a solution that is most consistent with diverse model processes and observational constraints. For example, we may find that assimilating only water variables, such as soil moisture, has a difference set of impact on energy, water and carbon exchanges than joint assimilation of carbon and water variables.

2. **ABL process representation:**

To what extent are the properties of the atmospheric boundary layer (ABL) defined by sensible and latent energy and water exchanges at the Earth's surface versus within the atmosphere (i.e., horizontal advection and ABL-free atmosphere exchanges)?

- **SoilWat** is paying particular scientific attention to arid and semi-arid regions, where surface fluxes are sensitive to soil moisture and convective events are frequent. Furthermore, it is also very crucial to understand the role of the Third Pole Environment (TPE) on affecting ABL and the ABL-free atmosphere exchanges, due to its unique land surface processes and high altitude. In this context, SoilWat is collaborating with the LS4P project. SoilWat is also contributing to the GABLS project.
- Key research activity of **GLAFO**. First results can be expected soon. New metrics will be available to investigate the feedback between surface fluxes and ABL development including entrainment.
- **LoCo** is at the core of this question as well, in that LoCo metrics and science are specifically focused on quantifying the impact of surface fluxes on the PBL (and vice-versa). LoCo has been a leader in demonstrating these feedbacks, as well as identifying the need for better observations particularly of the PBL. As LoCo considers how to expand beyong the 1-D paradigm, questions of horizontal scale and transport in the PBL will become important as well.
- **CLASP**: Under convective boundary layers, cloud development is enhanced when there are strong surface thermal gradients. This effect is caused primarily by the thermal gradients driving the development of the secondary circulations that then enhance the cloud production. Implementation of these types of approaches in global models will facilitate an

improved understanding of the role of surface heterogeneity on ABL processes and thus cloud development.

- **SIF-MIP** modeling protocol currently does not account for land surface feedbacks to the atmosphere, but this is an interesting and important direction for SIF-MIP.

3. **Understanding Circulation controls:**

To what extent are exchanges between water, energy and carbon determined by the large-scale circulations of the atmosphere and oceans?

- **SoilWat**: The link between land surface states/fluxes (soil moisture, groundwater) and the large-scale circulations has been progressing in past decades; for example, the fully coupled Earth System Modelling (& Data Assimilation), FLUXNET, and many others. Nevertheless, the existing Earth observation data are not yet sufficient to enable the observation-based quantification of such interactions. A vivid example is the Tibetan Plateau, where the Soil Moisture and Ocean Salinity (SMOS)/SMAP soil moisture "daily" products are only available for those summer months, limiting the study on the link between soil moisture and circulation. There is perhaps a scope here to link with the GEWEX Central Asia effort, as we are dealing here with vast, land-locked semi-arid areas where moisture recycling is an important phenomenon.
- Some contributions expected in the regions of current **GLAFO**s.
- **SIF-MIP** modeling protocol currently focuses on single point runs, but eventually will be more regional and global and nature, and which point large-scale circulation impacts can be examined.

4. **Land-atmosphere interactions:**

How can we improve the understanding of the role of land surface-atmospheric interactions in the water, energy and carbon budgets across spatiotemporal scales?

- **SoilWat** aims to improve representation of soil processes in climate models, which will ultimately improve the understanding of land-atmosphere interactions. The direction we are pushing is to realistically represent the coupling mechanisms among water, energy and carbon cycles in the soil and above ground.
- By developing and employing integrated metrics [**LoCo, International Land Model Benchmarking (ILAMB), PLUMBER2**] to confront our models, facilitated by improved observations (for both evaluation and assimilation)
- **CLASP**: There is a growing recognition that the community should focus on how surface heterogeneity impacts turbulence and mean advection at the surface and thus its impacts on surface fluxes, which remains a persistent weakness in land surface models. The role of microscale circulations and how moisture and heat are transferred between sub-grid units is seen as the next frontier in these efforts.
- L-A interactions will also be studied in detail using **GLAFO** observations.
- **SIF-MIP** has envisioned approaches for examining land-atmosphere interactions by coupling a subset of our models to atmospheric models, such as the Climate Modeling Alliance (CLIMA)

Goal # 3 (GS3): Quantify anthropogenic influences on the water cycle and our ability to understand and predict changes to Earth's water cycle.

1. **Anthropogenic forcing of continental scale water availability:**

To what extent has the changing greenhouse effect modified the water cycle over different regions and continents?

- **SoilWat and SIF-MIP**: Since anthropogenic forcing is represented by elevated atmospheric CO_2 concentration, this point is largely linked to photosynthesis, and the sensitivity of stomatal conductance to CO_2 concentrations, and the plant's acclimation to increased CO_2 concentration (and air temperatures). We need rich data sets of coordinated physiological and environmental measurements to enable the evaluation of various modeling approaches for the representation of the response of stomata conductance to CO_2 concentrations (and, therefore, the response of land surface fluxes to anthropogenic forcing). In this context, it is also important to acknowledge the role of soil respiration; these fluxes have been and will be undergoing considerable changes in the future, because of the change in soil temperature, soil moisture content and related rates of decomposition.
- **SIF-MIP** experiments could in principle examine scenarios with changes in forcing from atmospheric CO_2 and climate.

2. **Water management influences:**

To what extent do water management practices and land use change (e.g., deforestation) modify the water cycle on regional to global scales?

- **SoilWat** aims to understand water, energy and carbon fluxes over a range of biomes, including dry lands, where deforestation rate is the largest. Such change of land cover(use) will have large impacts on irrigation management, which will not only significantly modify the water cycle, but also local climate systems (e.g., local advection effect, more afternoon rain over dry soils). Furthermore, changes in land use/land cover will change the soil hydraulic and thermal properties, which will in turn impact the land surface water, energy and carbon fluxes.
- To be studied with **GLAFO** long-term measurements near Stuttgart, Germany, as this is an agricultural site.
- There are direct connections of **LoCo** with irrigation practices, groundwater withdrawal andland use change as the impacts of these surface changes are felt in the atmosphere (PBL, hence L-A interactions). For example, introducing irrigation in coupled models will significantly alter the water cycle, and if not performed realistically, will severely hamper water and energy cycles and NWP/GCM predictive capabilities. This has led to the development of the GEWEX **irrigation cross-cut activity** to systematically explore this topic.
- Also relevant is that these water management influences create heterogeneity at the surface that needs to be better captured in models at the native scales of heterogeneity. The CPT/**CLASP** project is directly addressing this in GCM world, but the questions are broader and impact NWP, mesoscale and LES as well. Understanding the role of heterogeneity in L-A and atmospheric circulations is an active topic of research.
- **SIF-MIP** experiments could in principle be extended to agricultural sites to examine impacts of management on carbon, and vice versa.

3. **Variability and trends of water availability:**

How do water & land use and climate change affect the variability (including extremes) of the regional and continental water cycle?

- Future **SIF-MIP** experiments operating at the regional scale, using satellite observational constraints, could tackle these larger scale questions.

Other Key Science Questions
1–3 suggestions that you anticipate your community would want to tackle in the next 5-10 years within the context of a land-atmosphere project

- SoilWat How do PTF/soil properties and detailed descriptions of soil processes impact land surface fluxes/states? Can this be assessed using intelligent, physically meaningful metrics? This could include soil respiration dynamics coupled with soil moisture and heat dynamics (e.g., in thawing permafrost), and how can these interactions be linked to a broader discussion of the soil component of greenhouse gas emissions (N_2O, CH_4)?
- **GLAFO**: Understand the L-A feedback chains over the regime of soil moisture conditions, vegetation properties and in dependence of large-scale forcing; study and quantify the effects of land use and land cover changes (LUCC) on regional weather and climate; advanced simulation of extreme events
- **LoCo**: How will we improve measurement and modeling of land-atmosphere interactions over managed (agricultural) and built (urban) environments with limited datasets on human practices, built area, irrigation types, etc.? How can LoCo metrics (integrated, process-level assessment) better inform and be integrated into operational model development cycles, given the limited bandwidth of operational center development and model inflexibility? How can we harness the information in new observations of LoCo variables (e.g., soil moisture, fluxes, PBL) and utilize them properly in fully coupled L-A models and L-A data assimilation (which today does not exist)?

Contributions to WCRP including the WCRP Light House Activities
Briefly list any specific areas of your panel's activities in particular to the WCRP Light House Activities (Digital Earth, Explaining and Predicting Earth System Change, My Climate Risk, Safe Landing Cimates and WCRP Academy) https://www.wcrp-climate.org/lha-overview.

- Scientists within and connected to **SoilWat** are working towards a Soil-Plant Digital Twin (2023 GLASS Annual Report Page 10 of 14)
- Digital Earth: **LoCo** has strong relevance in terms of high resolution coupled model assessment/development, and data assimilation impact assessment. "Operational model diagnostic framework" development needs to be approached in integrated, process-level fashion (not old school, one-at-a-time, 500mb heights, etc.).
- Explaining and Predicting Earth System Change: This relates to GS1 above. **LoCo** has relevance here in identifying persistent errors in GCMs via coupled metrics, and identifying where observational network improvements need to be made.
- WCRP Academy: **LoCo** has always been a community outreach effort, in particular engaging young scientists to think about these challenging L-A interaction questions in new ways and to address global issues on a range of scales from GCM to NWP to LES.

Cooperation with other WCRP Projects, Outside Bodies and links to applications
e.g. CLIVAR, CliC, SPARC, Future Earth, etc.

- **GLAFO**: WCRP Representative Concentration Pathways (RCPs), TeamX, LIAISE; AmeriFlux; Critical Zone Observatories (CZos); NASA Hydrological Testbed

- Food Baskets: New **LoCo** initiatives to support campaigns and modeling studies focused on irrigation and impacts on WEC
- Extremes: New projects implementing **LoCo** metrics focused on drought, dry/wet extremes and feedbacks
- **SoilWat** will potentially contribute to the evaluation/assessment of crop/agriculture water productivitiy, as such contributing to "Water for the Food Baskets", "farm to fork".
- Outside bodies: the **SoilWat** initiative is intricately linked to the activities by the International Soil Modelling Consortium (ISMC): https://soil-modeling.org.

Workshops and Meetings

List of Workshops and Meetings Held in 2023

Meeting title, dates and location.

- GLASS Panel Meeting at the University of Hohenheim, Stuttgart, Germany, 15–17 August 2023
- GABLS meeting, 25 September 2023, online
- CLASP meeting, Princeton, New Jersey, 18 May 2023
- The joint ET-CC LIAISE workshop took place in Lleida between 27–29 March 2023, with various GLASS members & liaisons presenting and attending
- GLAFO Meeting in Cabauw, 22 August 2023
- GLAFO GLASS discussion, 8 February 2023, online
- GLAFO discussion at NCAR, Boulder, Colorado, 13 January 2023
- GLAFO presentation at AMS Annual Meeting in Denver, Colorado, 8 January 2023
- Aspen Global Change Institute (AGCI) Irrigation workshop, Aspen, Colorado, US, 4–9 June 2023
- Non-GEWEX event attended by many in the GLASS-GHP cross-cut irrigation project group
- Irrigation CC Virtual Meeting, 1 November 2023
- Irrigation CC Virtual Meeting, 7 December 2023
- ISMC-SoilWat Breakout "Soil Thermal Properties Working Group Meetings" (Biannual), online
- ISMC-SoilWat Breakout "Soil Math" (biweekly), online
- ISMC-SoilWat Breakout "Global soil carbon modelling" (monthly), online
- ISMC-SoilWat Breakout meeting at EGU, Vienna, Austria, April 2023
- LoCo L-A sessions convened at AMS23
- AMS PBL and Turbulence Workshop, Denver, Colorado, January 2023

List of Workshops and Meetings Planned in 2024 and 2025

Meeting title, dates and location and anticipated travel support needs.

- Quarterly virtual Irrigation CC meeting – June 2024
- Quarterly virtual Irrigation CC meeting – September 2024
- Quarterly virtual Irrigation CC meeting – December 2024 Virtual meetings – no travel support needed
- Although ILAMB activity has stalled somewhat due to funding issues, there are plans for a model benchmarking workshop for fall 2024 or spring 2025 next year. Forrest is in negotiation with DOE about where we could hold a meeting.
- GABLS/GLAFO online meeting, 6 February 2024

- Visit of potential GLAFO site in Brazil (Santarem), March 2024
- GLAFO meeting at EGU, Vienna, Austria, April 2024
- Various project presentations and discussions at GEWEX OSC in Sapporo, Japan, July 2024 (including GLAFO, SoilWat, PLUMBER2, Groundwater CC)
- Following on from our past **GEWEX-ISMC** workshops in Leipzig, Germany (2016) and with key SoilWat members in attendance at the first **ET-CC** meeting in Sydney (https://soil-modeling.org/activities/soilwat/gewex-soilwat-initiative), we plan to hold a 2nd **GEWEX-ISMC** meeting in the early summer of 2025, probably at the University of Reading. A separate funding request has been submitted.

Other Meetings Attended On Behalf of GEWEX or Panel in 2023

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Publications during Reporting Period

List of Key Publications

Abramowitz, G., A. Ukkola, S. Hobeichi, J. Cranko Page, M. Lipson, M. De Kauwe, S. Green, C. Brenner, J. Frame, G. Nearing, M. Clark, M. Best, P. Anthoni, G. Arduini, S. Boussetta, S. Caldararu, K. Cho, M. Cuntz, D. Fairbairn, C. Ferguson, H. Kim, Y. Kim, J. Knauer, D. Lawrence, X. Luo, S. Malyshev, T. Nitta, J. Ogee, K. Oleson, C. Ottlé, P. Peylin, P. de Rosnay, H. Rumbold, B. Su, N. Vuichard, A. Walker, X. Wang-Faivre, Y. Wang, and Y. Zeng, 2024. On the predictability of turbulent fluxes from land: PLUMBER2 MIP experimental description and preliminary results. *EGUsphere* [preprint], https://doi.org/10.5194/egusphere-2023-3084.

Bauer, H.-S., F. Späth, D. Lange, R. Thundathil, J. Ingwersen, A. Behrendt, and V. Wulfmeyer, 2023. Evolution of the convective boundary layer in a WRF simulation nested down to 100 m resolution during a cloud-free case of LAFE, 2017 and comparison to observations. *Journal of Geophysical Research: Atmospheres*, 128, e2022JD037212, https://doi.org/10.1029/2022JD037212.

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Fan, Y., E. Im, C. Lan and M. Lo, 2023. An Increase in Precipitation Driven by Irrigation over the North China Plain Based on RegCM and WRF Simulations. *J. Hydrometeor.*, 24, 1155–1173, https://doi.org/10.1175/JHM-D-22-0131.1

Fowler, M.D., R.B. Neale, J.S. Simon, D.M. Lawrence, N.W. Chaney, P.A. Dirmeyer, V.E. Larson, M. Huang and J. Truesdale, 2023. Assessing the atmospheric response to subgrid surface heterogeneity in CESM2. *J. Adv. Mod. Earth Sys*. (in revision).

Hay-Chapman, F.M., and P.A. Dirmeyer, 2023. A novel method for diagnosing land-atmosphere coupling sensitivity in a single-column model. *J. Hydrometeor*., 24, 2207–2223, doi: 10.1175/JHM-D-22-0237.

Hsu, H., and P.A. Dirmeyer, 2023. Soil moisture-evaporation coupling shifts into new gears under increasing CO_2. *Nature Comm.*, 14, 1162, doi: 10.1038/s41467-023-36794-5.
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2.4.1. GLASS Panel Rapporteurs Report

Panel: Global Land-Atmosphere System Studies (GLASS) Panel
Rapporteur(s): Martin Best and Richard Forbes

Adherence to GEWEX and Panel's objective(s)

GLASS activities contribute to the following GEWEX Science Goals:

- Goal #1: Determine the extent to which Earth's water cycle can be predicted:
  - Reservoirs and the rate of expansion of the fast reservoirs (atmosphere and land surfaces) and the extent to which they are predictable
  - Flux exchanges - the extent to which the fluxes of water between Earth's main reservoirs are changing and whether these changes can be predicted
- 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:
  - Forcing-feedback understanding: How can we improve the understanding of climate forcings and feedbacks formed by energy, water and carbon exchanges?
  - ABL process representation: To what extent are the properties of the atmospheric boundary layer (ABL) defined by sensible and latent energy and water exchanges at the Earth's surface versus within the atmosphere (i.e., horizontal advection and ABL-free atmosphere exchanges)?
  - Understanding circulation controls: To what extent are exchanges between water, energy and carbon determined by the large-scale circulations of the atmosphere and oceans?
  - Land-atmosphere interactions: How can we improve the understanding of the role of land surface-atmospheric interactions in the water, energy and carbon budgets across spatiotemporal scales?
- Goal #3: Quantify anthropogenic influences on the water cycle and our ability to understand and predict changes to Earth's water cycle.
  - Water management influences: To what extent do water management practices and land use change (e.g., deforestation) modify the water cycle on regional to global scales?
  - Variability and trends of water availability: How do water & land use and climate change affect the variability (including extremes) of the regional and continental water cycle?

Achievement of annual goals and Major accomplishments and results for this reporting period

- GLAFO: Observing surface exchange, soil and atmosphere.
- New site approved. Two more under discussion (and perhaps more in the US).
- Observational capability to underpin future projects.PLUMBER2: Journal paper submitted.
- SIF-MIP and SoilWat: Multiple model engagement. Analysis being undertaken.
- LoCo: Continues to influence local coupling components and aspects of field campaigns
- Irrigation CC: Coordination of datasets. Special issue and telecon meetings.

Arisen or noted science issues

- ET CC, ILAMB and modelevaluation.org: Unclear what the next steps for these projects are
- GSWP3 and LS3MIP are projects ready to be sunsetted.

Emerging Science

- CLASP: Great potential for future international engagement

Future plans

- Development of four projects:
  - Groundwater Cross-cut
  - GLAFO-GABLS-LoCo Cross-cut
  - ML4LM (Machine learning for land modeling)
  - VaaSS (Vegetation as a soil sensor)

Recommendations to Panel

- Projects need to be bottom up: inspired by motivated scientists
- Projects should directly contribute towards the GEWEX science goals and WCRP objectives
- Panel members should focus around:
- Funded projects
- Development of new projects aimed towards funding opportunities
- Research/projects that are necessary but would not have been organized if GLASS didn't exist
- Panel should not try to do everything! Motivate the community to tackle key science challenges
- Organization of a Pan-GLASS meeting in 2026 including joint session(s) to inspire cross cut working

Considerations for SSG

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Additional Remarks

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2.5. CLIVAR/GEWEX Monsoons Panel

Full Panel Name (Acronym) : CLIVAR/GEWEX Monsoon Panel
Reporting Period : 01 January - 31 December 2023
Starting Date : 2014
End Date (where appropriate): N/A
URL : https://www.clivar.org/clivar-panels/monsoons

Membership

Chair(s) : Leila Carvalho
Suryachandra Rao Anguluri

Background

The CLIVAR/GEWEX Monsoons Panel (MP) was established in 2014 with the remit of: (a) taking a more global view of monsoon activities, enabling knowledge and best practice to be shared between the various monsoon regions and (b) to better coordinate monsoons research between GEWEX and CLIVAR, particularly in emphasizing the role of convection and the land surface in the monsoons. The MP membership encompasses the research interests of both CLIVAR and GEWEX as well as all the regional monsoons, with in-country membership where possible. While the MP takes a global view, it is also important to address region-specific details, particularly in engaging regional stakeholders and managing local knowledge exchange and up-skilling. Keeping this in view, the MP has established a sub-structure of working groups (WGs) dedicated to three monsoon regions, namely the Asian-Australian (WG-AAM), African (WG-AFM) and American (WG-AMM) Monsoons.

The three regional monsoons WGs are working towards enhancing understanding of the monsoons in those regions through various process studies with an emphasis on improving prediction skills in those respective areas. The primary focus of these groups is to build a partnership between operational met departments and researchers that is intended work on various strengths and limitations of the present climate models in predicting weather and climate in those regions. The regional working groups also establish sub-groups to focus on different topics. In these sub-groups, researchers beyond working groups, particularly Early Career Scientists (ECS), are engaged in various studies to address the significant issues of the regional WGs. The MP guides the WGs on multiple tasks and research priorities and in promoting cross-cutting activities and synergies among groups.

See the Monsoons Panel web pages for Terms of Reference (ToRs), membership and previous reports:

- http://www.clivar.org/clivar-panels/monsoons
- https://impo.tropmet.res.in/wcrp-monsoon.html

Activities of the MP are supported by the International Monsoons Project Office (IMPO), hosted at the Indian Institute of Tropical Meteorology (IITM), Pune, India, under a new agreement signed between WMO and IITM on 30th July 2021. IMPO also supports the monsoon activities of the Working Group on Tropical Meteorology Research (WGTMR) of the World Weather Research Programme (WWRP), facilitating the MP's linkages with WWRP monsoon activities.

MP's current main missions

The MP coordinates strategies, advises on plans and defines concrete activities to carry out studies on the suggested research priorities, including selecting, limiting and concluding such

activities as appropriate. MP encourages studies on priority themes by groups from different monsoon domains and facilitates and/or promotes collaboration among monsoon researchers. MP stimulates the interest of researchers and students in monsoon related problems by supporting and organizing workshops and advanced schools and promoting scientific sessions in conferences with a focus on monsoons. MP also coordinates the formation and function of regional working groups and collaborates with the WCRP and WWRP substructures relevant to monsoon research regarding the organization of scientific meetings and regional working groups, as well as on relevant issues for advancing monsoon research. Finally, MP supports work in cooperation with regional, national and multinational programs to enhance the understanding of monsoon systems and improve monsoon prediction from synoptic to decadal time scale and longer, setting strategic priorities for long-term climate projection. MP also has a mission to communicate existing products and provide guidance on their (adequate) application and limitations to the operational community, (relevant) impacts community and participate in relevant training activities.

The current goal of the MP is to identify the bottlenecks to further improve the skills of dynamical models in representing the monsoons on multi-spatiotemporal scales, including extreme weather. The activities lined up for addressing these activities include:

- Assess and improve the skill of monsoon rainfall in different regional monsoons and identify the bottlenecks in the dynamical models.
- Improve understanding of dynamical and physical processes associated with extreme events and identifying the lacuna in capturing these extremes in present-day models.
- Promote Research to Operations (R2O) activities to contribute to the Regional Climate Outlook Forums (RCOFs) and operational meteorological services.
- Build capacity by promoting ECS representation in the WGs and subgroups developing these activities

MP's 2023 Activities

Organizational Activities

The Fifth Session of CLIVAR/GEWEX Monsoons Panel was held on 27th October 2023 during WCRP/OSC-2023 in Kigali, Rwanda in hybrid mode (with 5 members attending in-person and 3 online). A special in-person meeting of MP and WG-AFM members (with 10 members attending in-person and 3 online) was also organized on 27th October 2023. Jan Polcher (GEWEX SSG Co-chair) attended the whole meeting (2.5 hours long) and gave his valuable suggestions/comments. A photo displaying the session in-progress is given in Appendix-I.

In addition, MP held four virtual meetings in 2023, which have served as discussions on the highlights of the activities of MP, its regional WGs and their future work plans. In addition, the two co-chairs also held a few infrequent teleconferences.

- WG-AFM held six virtual meetings to discuss on the writing of a review article on "Climate Modeling of Precipitation over Africa" and the activities of their three sub-groups (Viz., South & East Africa, West Africa, and Central Africa)

- WG-AAM held four virtual meetings to discuss on the activities of the group and its three sub-groups (Viz., Monsoon Processes and Teleconnections; R2O for monsoon seasons in SE Asia; High Impact Weather Events) and on the Asian/Australian (summer) Monsoon 2023.

- WG-AMM had only email exchanges among its members to discuss their activities. MP was actively involved in the selection and appointment of the three new members to the panel (Dr. Ruth Cerezo-Mota, Prof. Hui Su and Dr. Hiroshi Takahashi) in February 2023.

MP was also actively involved in the selection and appointment of the two new members of WG-AMM (Dr. Caio Augusto dos Santos Coelho and Dr. Robin Chadwick) in June and August 2023, respectively. The details of the current memberships of MP and the regional working groups are available at the following links:

- CLIVAR/GEWEX Monsoons Panel (14 members; Female: 7, Male: 7)
- Co-Chairs: Prof. Leila M.V. Carvalho and Dr. Suryachandra Rao Anguluri
- https://impo.tropmet.res.in/wcrp-monsoon.html;
- Asian-Australian Monsoons (17 members; Female: 6, Male: 11)
- Co-Chairs: Dr. Gill Martin and Dr. Tieh Yong Koh
- https://impo.tropmet.res.in/mpwg-aam-members.html;
- African Monsoons (21 members; Female: 8, Male: 13)
- Co-Chairs: Dr. Rondrotiana Barimalala and Dr. Akintomide Afolayan Akinsanola
- https://impo.tropmet.res.in/mpwg-afm-members.html;
- American Monsoons (15 members; Female: 7, Male: 8)
- Co-Chairs: Dr. Alice Grimm and Dr. Ruth Cerezo-Mota
- https://impo.tropmet.res.in/mpwg-amm-members.html

About seventeen (17) members of MP and its regional working groups are early career researchers.

Scientific Activities

- Leila participated in the 27th Session of CLIVAR SSG on 2nd February 2023 and presented the recent activities of MP and its Regional Working Groups online.
- Surya participated in the GEWEX SSG meeting in-person during 1–4 May 2023 in Santiago, Chile and presented the recent activities of MP and its Regional Working Groups.
- Surya participated in the 28th Session of CLIVAR SSG on 22 and 27 October 2023 at Kigali, Rwanda.

Achievements for 2023

Workshops

- South Asian Climate Outlook Forum (SASCOF): Suryachandra Rao gave a talk on behalf of the WG-AAM entitled "Status of seasonal predictions for Asian monsoon and how to improve outlook reliability" at SASCOF (24–26 April 2023). Several WG-AAM members attended and presented seasonal outlooks at this meeting.
- Association of Southeast Asian Nations Climate Outlook Forum (ASEANCOF): The R2O subgroup gave a presentation at ASEANCOF (25 May) describing its aim to develop a regional monsoon index for Southeast Asia, results from the questionnaire during ASEANCOF-18 and a brief description of the proposed regional monsoon index. Discussions during ASEANCOF highlighted that the impact of ENSO on the boreal summer monsoon (SW monsoon) is not uniform across Southeast Asia, therefore any regional monsoon index should capture this (and other) differences.

- Members of the MP and working groups were actively involved in the WCRP OSC-2023:
- Izidine Pinto (WG-AFM) functioned as a Theme Lead for “Theme 2: Human Interactions with Climate" and a Convenor of Session “S24: Attribution of changes”.
- Suryachandra Rao A. (MP) and Tereza Cavazos (WG-AMM) were the Convenors ofsession “S03: Global and Regional Monsoons”.
- Caio Augusto dos Santos Coelho (WG-AMM) was a Convenor of Session 28: "Regional Information – Data and Methods" and also delivered an oral talk on “Cascading multi-model sub-seasonal predictions from global to regional and local scales” in the same session.
- Two Poster Clusters (PC) proposed by members of WG-AFM and WG-AMM and WG-AAM were presented online and displayed in the poster sessions.
- Alice Grimm (Co-chair, WG-AMM) delivered a keynote talk on “Major issues and challenges for the American monsoons” in Session 03: Global and Regional Monsoons.
- Rondrotiana Barimalala (Co-chair, WG-AFM) delivered a keynote talk on “Major issues and challenges for the African monsoons” in Session 03: Global and Regional Monsoons.
- Masilin Gudoshava (WG-AFM) delivered a keynote talk on “The objective seasonal forecasting approach over Eastern Africa: Benefits, challenges and future prospects” in Session 28: Regional Information – Data and Methods.
- Paul-Arthur Monerie (WG-AFM) delivered an oral talk on “A zonal contrast in future changes in Sahel precipitation” in Session 37: Regional Attribution.
- Leila Carvalho and Suryachandra Rao A (MP Co-chairs) are the Co-Lead authors of the Concept Paper on Regional and Global Monsoons for the OSC Kigali Declaration with Michelle Simões Reboita and Tereza Cavazos (WG-AMM), Neil Hart and Rondrotiana Barimalala (WG-AFM), Kieran Hunt (WG-AAM) and Hiroshi Takahashi (MP) as co-authors.
- Poster Presentations in OSC-2023:
- Shiromani Jayawardena (WG-AAM) - Predictability of extreme rainfall event using ECMWF Extreme Forecast Index Case Study: Heavy Rain event in Sri Lanka from 1st to 3rd August 2022
- Shiromani Jayawardena (WG-AAM) - Future projections of heat wave activity for Colombo area under moderate and high emission scenarios
- Gill Martin (WG-AAM) - Understanding the development of systematic errors in the Asian summer monsoon
- Thea Turkington (WG-AAM) - A Regional Monsoon Index for Southeast Asia
- Shingirai Nangombe (WG-AFM) - Attribution of climate change attribution of the 2018 early summer drought in south southern Africa
- Neil Hart (WG-AFM) - The decline of tropical-extratropical cloud bands in the Southern Hemisphere subtropics
- Mojisola Adeniyi (WG-AFM) - Simulation of the impacts of 1.5°C to 3°C regional warming levels on heat related death over West Africa
- Paul-Arthur Monerie (WG-AFM) Uncertainty in future changes in Sahel precipitation: a role of the warming of the North Atlantic and Euro-Mediterranean areas.
- Caroline Wainwright (WG-AFM) - Investigating the Drivers of Dry Season Rainfall over Eastern Africa
- Kieran Hunt (WG-AAM) - The future of low-pressure systems in the Indian monsoon
- Kieran Hunt (WG-AAM) - Non-linear intensification of monsoon low-pressure systems by the BSISO

- Pankaj Kumar (MP) - A Regional Earth System Modelling framework for Monsoon studies over CORDEX-SA region
- Ajaya Mohan Ravindran (MP) - Atlantic Zonal Mode: An emerging source of Indian summer monsoon variability in a warming world
- Michelle Simões Reboita (WG-AMM) - Weather and Climate of South America: A Review
- Michelle Simões Reboita (WG-AMM) - Response of the Southern Hemisphere Extratropical Cyclone's Climatology to the Solar Radiation Management
- Suryachandra Rao A. (MP) - Impact of Bay of Bengal Eddies on Indian Summer Monsoon Rainfall
- Rachel James (WG-AFM) - The SALIENT Research Programme: combining adaptation-led climate science and learning from psychology and risk communication to improve understanding of possible, plausible and probable futures
- Alice Grimm (WG-AMM) - Changes in the South American monsoon phases under El Niño–like future warming

Scientific Results from Activities

Scientific Results from WG-AAM:

- *Monsoon Processes and Teleconnections (MPT) subgroup:* This subgroup has been examining the prediction skills of wintertime surface air temperature in Copernicus Climate Change Service (C3S) models preliminarily for the Asian region. The skill is found to be high in the subtropical regions and much lower in the mid- and high-latitude inner lands. The capability of the models to capture the observed temperature modes was also evaluated, but the results are very sensitive to the choice of domain. A paper is being drafted which will describe the skill of Subseasonal to Seasonal predictions and bottlenecks, and why teleconnections to Niño sea surface temperatures (SSTs) are poor.
- *Research to Operations for monsoon seasons in SE Asia (R2O) subgroup:* This subgroup meets quasi-monthly and has been exploring a wind-based definition for monsoon seasons in SE Asia that draws upon research published by Lee and McBride (2016). An original formulation for the South-East Asian Monsoon Progression Index (SEAMPI), when tested using NCEP/NCAR and ECMWF reanalyses, revealed sensitivity to the nominal definition of the windows in which we look for the onsets and terminations of northerly and southerly monsoons. The group has since been working on a revised approach to identifying reference monsoon winds in SE Asia. This work was presented at ASEANCOF-20 in May, where it was well received. A poster on the work will be presented at WCRP OSC in October 2023.
- *High Impact Weather Events (HIW) subgroup:* Case studies of high impact events from recent years have been reviewed to see how they were observed and forecast, and how decision-making was affected. The group has discussed the disconnect between seasonal outlooks, which are for the country and season as a whole, and the variability on sub-seasonal and medium-range timescales, plus extreme events, that are experienced on the ground. Some countries have no capacity for creating sub-seasonal outlooks, despite a pressing need for landslide and lightning forecasts. There is also a lack of consistency in how each regional met service communicates the risks of extreme events, as inferred from the seasonal outlooks, to their stakeholders. A draft document is being written on this topic, with examples contributed by WG members documenting the issues based on some benchmark extreme event case in their respective region.

- *Unusual characteristics of monsoons 2022:*

  As reported last year, the WG-AAM considers the unusual characteristics of the 2022 summer monsoon season to be worthy of study and documentation. We have continued to pursue this, although progress on this has been slow due to personal circumstances and commitments. However, there is still enthusiasm for taking this forward. An outline structure was discussed whereby the emphasis would be on the unusual large-scale characteristics of the Asian Summer Monsoon 2022 (including displaced monsoon trough and associated larger scale circulation variations affecting dynamical indices and path/frequency of monsoon lows and tropical depressions crossing India, Pakistan, E Asia, and low-level flow transporting moisture to Sri Lanka and Indonesian Islands, Maritime Continent, etc.) and how this relates to the extreme events experienced in various regional monsoons.
- One of the WG meetings featured a detailed presentation by Shiromani Jayawardena on the winter monsoon events of 2022/23 and the seasonal forecasts for this period issued by the Sri Lankan Meteorological Department.
- Since 2023 has also been a somewhat unusual year for the boreal summer monsoons, a specific meeting has been arranged for November 2023 to discuss this year's AAM and sub-regional characteristics. A research paper or newsletter article comparing the contrasting monsoons in 2023 and 2022 is also being considered.

Scientific Results from WG-AFM:

- The West Africa subgroup is analyzing the representation of the mesoscale convective systems over West Africa using DYAMOND data. Significant progress has been made, and hopefully the results will be ready early next year.
- The Central Africa subgroup is currently assessing the role of Central Africa in modulating the regional monsoons.
- Some of the South-East and Central Africa teams are involved in a "taskforce for understanding the eastern Africa March-May rainfall". There is a discussion on writing a white paper about the critical need for observational data and a comprehensive field campaign in the area, to be co-led by members of the AFM-WG with other senior scientists who have experience from the African Monsoon Multidisciplinary Analysis (AMMA) program. This idea was also suggested to be included in the GPEX lighthouse activity.
- The entire working group is currently revising a review paper titled "Climate Modeling of Precipitation over Africa: Progress, Challenges, and Prospects." The manuscript reviews our current knowledge of the modeling of African precipitation and, more importantly, identifies the gaps that need to be addressed by the research community.
- Since all members in the WG group are new, a mapping of the expertise and projects in which each member is involved was conducted in order to improve the collaboration and the focus of the subgroup.

Scientific Results from WG-AMM:

Members have engaged with Climate Outlook Forums and organized or taken part in a number of conferences, workshops, and meetings, several of them with participation of stakeholders, civil defense personnel, and students. These activities have been enhanced in view of the present El Niño event 2023–2024, which will impact on the monsoons season, and the increased interest about climate change impacts following the change of government in Brazil.

Scientific Capacity Building and Career Support

- MP played a key role in the successful organization of the first Joint WCRP/WWRP Webinar Series on Global Monsoon held on 13th September 2023, which featured talks by eminent

scientists Prof. Bin Wang and Dr. Annalisa Cherchi. Dr. Suryachandra A. Rao (Co-Chair MP) chaired the webinar. A screenshot of the in-progress webinar is displayed in Appendix-II. Out of the 307 registered attendees, 175 attended the webinar. A video recording of the webinar has been made available in the IITM YouTube channel for wider reach and publicity, which already has 356 views.

- WG-AAM played a key role in the successful organization of the second Joint WCRP/ WWRP Webinar Series on Asian-Australian Monsoon held on 30th November 2023, which featured talks by eminent scientists Prof. B N Goswami and Dr. Tim Cowan. Drs. Gill Martin (Co-Chair WG-AAM) and Thea Turkington co-chaired the webinar. A screenshot of the in-progress webinar is displayed in Appendix-II. Out of the 228 registered attendees, 120 attended the webinar. A video recording of the webinar has been made available in the IITM YouTube channel for wider reach and publicity, which already has 220 views.
- Insights such as recent scientific advances from the WG-AAM meetings are shared with concerned operational and R&D activities of Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA), more specifically in the development and definition of a local monsoon index in the Philippines.
- Activities of the WG-AAM such as webinars, conferences and calls for career opportunities are shared to the technical personnel of PAGASA as a support for scientific capacity building on recent advances in monsoon community.
- It is noteworthy that the Philippines is represented in the WG-AAM considering that the WNP monsoon is largely observed in the Philippines.
- Caio Coelho (WG-AMM) participated in the online training activity of Scuola Internazionale Superiore di Studi Avanzati (or the International School for Advanced Studies, SISSA) on calibration of seasonal predictions, 14 June 2023, and delivered the talk "Calibration of seasonal forecasts".
- Caio Coelho (WG-AMM) participated in the virtual workshop of sub-seasonal prediction – Historical prediction database, organized by SISSA-RCC-SSA in collaboration with RCC-WSA, 27 September 2023, and delivered the talk on the Centro de Previsão de Tempo e Estudos Climáticos (CPTEC)/Instituto Nacional de Pesquisas Espaciais (INPE) experience in sub-seasonal predictions over South America.
- WG-AFM is in the process of organizing a training or workshop for African students and early-career researchers focusing on climate modeling, data analysis and other topics yet to be discussed.

Knowledge Exchange

- Several of the WG-AAM members are regular contributors to the Regional Climate Outlook Forums for the Asian-Australian region [SASCOF, ASEANCOF, East Asia winter Climate Outlook Forum (EASCOF)], allowing the group to provide guidance on model strengths and weaknesses and to reach out to stakeholders.
- Several WG-AAM members attended and presented at the EGU General Assembly in April in the session “Monsoon systems in the past and present and under future climate change” (Prof. Andy Turner, University of Reading):
- Kieran Hunt: Nonlinear intensification of monsoon low pressure systems by the BSISO
- Gill Martin: Why is there a systematic bias in the Asian Monsoon in the Met Office Unified Model?
- Several WG-AAM members attended and presented at the WWRP/WCRP S2S Summit, in Reading, UK during 3–7 July 2023. Donaldi Permana presented on “The impact of the BSISO on boreal summer rainfall anomalies in Indonesia” and Kieran Hunt presented on “Nonlinear intensification of monsoon low pressure systems by the BSISO”.

- Several WG-AAM members attended and presented at the AOGS 2023:
- Thea Turkington presented or co-authored several talks and posters and also chaired the session on “Subseasonal to Seasonal Forecasts and Applications”
- Wei Ting Chen presented or co-authored several talks and posters and also chaired the session on “The Physical Processes Over Complex Topography: The Interactions Among Meteorology, Boundary Layer Turbulence, Clouds, Tracer Transport, and Chemistry”
- Donaldi Permana presented or co-authored several talks and posters including “The Impact of Intraseasonal Oscillation and Equatorial Waves on Rainfall Extremes in Indonesia” (invited speaker)
- Lin Wang presented or co-authored several talks and posters including “Decadal Background for Active Extreme Drought Episodes in the Decade of 2010–19 Over Southeastern Mainland Asia”.
- Huqiang Zhang presented or co-authored several talks including an invited talk “High-Resolution Weather and Climate Modelling at CCRS: Current Status and Future Priorities”.
- Shiromani Jayawardena (WG-AAM) presented at the Workshop on Long Range Forecast for the 2023 Southwest Monsoon Season Rainfall and its application on South Asian Agriculture held on 13 May 2023 virtually: “Recommended Strategies in agriculture based on LRF 2023 in Sri Lanka”.
- The WG-AAM is organizing the second webinar in the Joint WCRP/WWRP Monsoons Panel webinar series on Global Monsoons, with talks on the impact of climate change on Indian monsoon and on the development and implementation of operational services for the Australian monsoon, followed by a discussion on outstanding challenges in monsoon predictions and projections on 30th November 2023.
- A group led by Ross Dixon (WG-AFM) has successfully proposed a session titled “African Climate Change and Variability”, to be conveyed at the AMS 2024 meeting.
- In the 75th Annual Meeting of the Brazilian Society for the Progress of Science (SBPC), held in Curitiba, 23–29 July 2023, Alice Grimm (WG-AMM) proposed two of the activities carried out in this event:
- Conference by Dr. Carlos Nobre on the need to preserve the Amazon forest and exploit it sustainably (26th July 2023)
- Round Table on Climate Change and its impacts on climate and biodiversity in Brazil, in which Prof. Alice Grimm delivered a talk on the impacts on climate in Brazil, especially during the monsoon season.
- In the Workshop on the 2023–2024 El Niño on 31st July 2023, organized by the Santa Catarina Association of Meteorologists (ACMET), Federal University of Santa Catarina, Civil Defense and State Company of Agricultural Research and Rural Extension of Santa Catarina, Prof. Alice Grimm (WG-AMM) delivered the Keynote Talk that opened the event, in which the impacts of the events in the monsoon season (spring, summer, early autumn) were described and explained. Researchers, students, civil defense personnel, stakeholders and the public took part of this event.
- In the 28th IUGG General Assembly, Berlin, 11–20 July 2023, Alice Grimm (WG-AMM) delivered an oral presentation on “Conditions associated with continuing and terminating MJO events during the monsoon season”, in the session M32b - Sub-Seasonal to Decadal Prediction (S2S-S2D), 15th July 2023
- In the WWRP/WCRP S2S Summit during 3 to 7 July 2023, University of Reading, UK, Caio Coelho (WG-AMM) gave a talk on “The S2S sub-project on Research to Operations (R2O): forecast and verification products development”. Felipe de Andrade (WG-AMM) gave a talk

on “Evaluating the representation of South America precipitation variability patterns in sub-seasonal predictions of S2S project models”.

- In the International Conference on Regional Climate ICRC-CORDEX 2023 | (ICTP, smr 3878), Michelle Reboita (WG-AMM) presented two posters:
  - A3-P-20: The South American Monsoon lifecycle projected by an ensemble of CMIP6-GCM statistically downscaled
  - A2-P-23: Assessment of homogeneous groups climatology simulated by RegCM-CP over southeastern South America
- Caio Coelho and Felipe de Andrade (WG_AMM) participated in monthly climate discussion meetings organized by CPTEC/INPE to discuss with Brazilian partner institutions [Instituto Nacional de Meteorologia (INMET)- Fundação Cearense de Meteorologia e Recursos Hídricos (FUNCEME)- Centro Gestor e Operacional do Sistema de Proteção da Amazônia (CENSIPAM)] the seasonal climate outlook for Brazil in the forthcoming season.
- Marcelo Barreiro (WG-AMM) has been attending the monthly meetings with the Uruguayan weather service (INUMET) to prepare the seasonal forecast.
- Alice Grimm (WG-AMM) delivered an invited talk on impacts of climate change on monsoon precipitation in Brazil during the event “Intelligence and climate change: action of public authorities in the face of natural disasters”, organized by the Brazilian Intelligence Agency (ABIN) in November 2023.

Cross-panel Activities

- Masilin Gudoshava (WG-AFM) is actively involved in the “My Climate Risk” LHA.
- Izidine Pinto (WG-AFM) is actively involved in “Safe Landing Climates” LHA.
- Caio Coelho (WG-AMM) is a member of the Expert team on Climate Services Information System Operations, co-chair of the Expert team on Operational Climate Prediction System, and co-chair of the Joint Working Group of Forecast Verification Research.
- The West African Sub-group of WG-AFM is currently looking at the GEWEX/GASS DYAMOND high resolution model outputs to see how the model represents the mesoscale convective system in the area and how does it affect the monsoon.
- Ismaila Diallo of WG-AFM is participating in the LS4P-IIproject of GEWEX/GASS and trying to see how we can use land surface to predict extreme events over control regions. Currently he is working on how to implement LS4P-II techniques to improve the prediction of weather extremes in Africa.
- Wei Ting Chen and Lin Wang of WG-AAM are identified to engage with the SPARC activity on Atmospheric Composition and the Asian Summer Monsoon (ACAM);note that contact with ACAM was finally established this month.
- Pankaj Kumar, Hui Su and Hiroshi Takahashi of MP are identified for collaborating with CliC on understanding the connections between the Himalayan cryosphere and Asian monsoons and impacts of reduced Arctic sea-ice on Asian monsoons.
- WG-AFM is in discussion with SPARC about co-organizing a workshop to foster more partnership between the global South and North regarding climate change and mitigation.
- Annalisa Cherchi (MP) is a member of EPESC LHA WG2, and she is starting to co-lead with Andrea Dittus coordinated activities within the WG about "Tropical circulation variability and trends”.
- Michelle Reboita is member of the American Monsoon Working Group and a collaborator of CORDEX South America and Central Asia domains and member of the Working Group on Tropical Meteorology Research (WGTMR-WMO).

- Jhan-Carlo Espinoza is a Co-Chair of the Regional Hydroclimatic Program (RHP) for the Andes, ANDEX, supported by GEWEX/WCRP. Since 2019, he has been a member of the Science Panel for the Amazon (SPA).

Plans for 2024 and Beyond

- Members of MP and the WGs will be involved as Guest Editors/Contributors for a special issue of *Advances in Atmospheric Sciences* on global monsoons, including the Asian monsoon, American monsoon, African monsoon and Australian monsoon.
- WG-AFM and WG-AMM will be actively involved in the organization of the Joint WCRP/WWRP MP Webinar Series on African and American Monsoons in early 2024.
- WG-AAM's Subgroup activities will continue and aim to publish results of work from past 1–2 years.
- The WG-AAM will aim to complete an article on the unusual characteristics of the past two years' Asian-Australian monsoons.
- Leila Carvalho (Co-chair, MP) is a member of the SSC of the "International Workshop on Stratosphere-Troposphere Interactions and Prediction of Monsoon weather EXtremes (STIPMEX)" being organized by IITM with the support from the Ministry of Earth Sciences (MoES), India Meteorological Department (IMD), IMPO, SPARC/ACAM, Forschungszentrum Jülich GmbH (Germany), SPARC/SSiRC and WWRP/WGTMR during 2–7 June 2024.
- Members of MP and WGs will be involved actively in MP-coordinated Monsoon Sessions at the GEWEX OSC in July 2024 at Sapporo, Japan.
- Several WG-AAM members will attend the GEWEX OSC in Japan during 7–12 July 2024 and also the joint meeting between MP and WG-AAM planned during that week.
- AOGS 2024: The need for further quasi-biennial WG-led sessions on "Asian-Australian Monsoon: linking research to operational needs" of this series is under review as there are other well-attended regular monsoon sessions at AOGS.
- In the WG-AFM, the Subgroup activities will continue and aim to publish the results of works from the past two years.
- Several members of WG-AFM will be attending AMS 2024 in Baltimore, Maryland.
- WG-AMM plans to organize the second Workshop and Advanced School on American Monsoons.
- WG-AMM plans to organize a special issue with articles on various aspects of American Monsoons.
- WG-AMM plans to organize webinars on the different aspects of the American Monsoons.
- MP and WGs will get involved with Pacific Region Panel and Ocean Model Development Panel (OMDP) to improve the ENSO teleconnections in models.
- MP and WGs will get involved in the **SynObs** Project for the evaluation of Ocean Observing System as a cross-panel activity.
- MP and WGs will provide ideas/activities for GPEX LHA which will be useful for the monsoon community.
- MP and WGs will attempt to build links with the other disciplines like agriculture, agronomy, hydrology and health.
- MP and WGs will be involved actively in the MP-coordinated Monsoon Sessions in IWM-8 in 2025 in New Delhi, India.

Articles Published in 2023 as part of MP Activities (if any)

Cavalcanti, I.F.A., C.A.S. Coelho, L.F. Rezende, J.L. Gomes and C. von Randow, 2022. Potential applications for climate services originated from the CLIMAX project. *Frontiers in Climate,* https://doi.org/10.3389/fclim.2022.932589.

Deoras, A., A.G. Turner, K.M. Hunt, and I.M.S.P. Jayawardena, 2023. The Influence of Weather Patterns and the Madden-Julian Oscillation on Extreme Precipitation Over Sri Lanka. *Geophysical Research Letters, 50(14),* p.e2023GL103727, https://doi.org/10.1029/2023GL103727.

Mohan, T.S., K.N. Kumar, R. Ashrit, G. Martin, J. Kumar, S. Mohandas, A. Sarkar and V.S. Prasad, 2023. Moist processes in NCUM global forecasts during the boreal summer monsoon, submitted to *Atmospheric Research*, July 2023.

Reboita, M.S., G.W.D.S. Ferreira, J.G.M. Ribeiro, R.P. da Rocha, and V.B. Rao, 2023. South American Monsoon Lifecycle Projected by Statistical Downscaling with CMIP6-GCMs. *Atmosphere, 14(9)*, 1380; https://doi.org/10.3390/atmos14091380.

Zilli, M.T., N.C.G. Hart, C.A.S. Coelho, R. Chadwick, D.C. de Souza, P.Y. Kubota, S.N. Figueroa, I.F.A. Cavalcanti, 2023. Characteristics of tropical-extratropical cloud bands over tropical and subtropical South America simulated by BAM-1.2 and HadGEM3-GC3.1. *Quarterly Journal of the Royal Meteorological Society*, https://doi.org/10.1002/qj.4470.

Budget and Other Needs for 2024 (in CHF)

MP has plans to convene two monsoon related sessions in GEWEX OSC, participate actively in the discussions on GPEX activities and to also organize an in-person meeting between MP and WG-AAM in Sapporo, Japan during 7–12 July 2024. For more details, please read Annex-A.

Contributions to Developing GEWEX Science and the GEWEX Imperatives

a) Datasets
- Monsoons Panel (MP) and its regional WGs use only the publicly-available observational and model datasets to study monsoons all over world to understand its unique features.
- Any observational datasets collected in future by MP members could contribute to GEWEX science development.

b) Analysis
- MP and its regional WGs are expected to develop new analysis tools and software that will be made available to the community.
- The preliminary theoretical development of a South-East Asian Monsoon Progression Index was completed using Climate Data Assimilation System (CDAS) and ECMWF Reanalysis v5 (ERA5) datasets.
- Hindcasts from different models were assessed to understand the strengths and limitations in South Asian Monsoon rainfall predictions.

c) Processes
- MP and its regional WG members are actively involved in process understanding and model treatment (e.g., precipitation, clouds, surface fluxes, coupling surface to atmosphere, aerosols, dynamics-physics coupling).

d) Modeling Activities
- Assess and improve the skill of monsoon rainfall prediction in different regional monsoons and identify the bottlenecks in the dynamical models.

- Improve understanding of dynamical and physical processes associated with extreme events and identifying the lacuna in capturing these extremes in present-day models.
- The West African Sub-group of WG-AFM is looking at the GEWEX/GASS DYAMOND high resolution model outputs to see how the model represents the mesoscale convective system in the area and how does it affect the monsoon.
- Ismaila Diallo (WG-AFM) is participating in the LS4P-II project of GEWEX/GASS and trying to see how to use land surface to predict extreme events over control regions.

e) Application
- MP and its regional WGs intend to suggest improvements in both weather and climate models through model evaluation, especially on extreme events.

f) Technology Transfer
- MP intends to promote Research to Operations (R2O) activities to contribute with the Regional Climate Outlook Forums (RCOFs) and operational meteorological services.

g) Capacity Building
- MP and its WGs are the main organizers of the Joint WCRP/WWRP MP Webinar Series:
- MP organized the first webinar on "Global Monsoon" on 13th September 2023 during 7-8:30 UTC and 175 attended the webinar out of the 307 registered attendees. The recording of the webinar is available in the IITM YouTube Channel Video, which already has 356 views.
- WG-AMM organized the second webinar on Asian-Australian Monsoon on 30th November 2023 during 7-8:30 UTC and 120 attended the webinar out of the 228 registered attendees. The recording of the webinar is available in the IITM YouTube Channel Video, which has already 220 views.
- WG-AFM organized the third webinar on African Monsoons was organized on 6th March 2024 during 14-15:30 UTC and 74 out of the 138 registered attendees. The recording of the webinar is available in the IITM YouTube Channel Video, which has already 136 views.
- Build capacity by promoting ECS representation in the WGs and subgroups developing these activities. About seventeen (17) members of MP and its regional working groups are early career researchers.
- Several of the members of WG on Asian-Australian Monsoons (WG-AAM) are regular contributors to the Regional Climate Outlook Forums for the Asian-Australian region (SASCOF, ASEANCOF, EASCOF), allowing the group to provide guidance on model strengths and weaknesses and to reach out to stakeholders.
- MP Co-chair and members will be coordinating Monsoon Sessions in GEWEX OSC in July 2024 at Sapporo, Japan.

Contributions to the GEWEX Science Questions and Plans to Include These

Observations and Predictions of Precipitation

Annalisa Cherchi (MP) contributed to a draft white paper on WCRP Global Precipitation Experiment as a representative of MP in the GPEX tiger team. MP members also made several suggestions to the draft white paper.

Global Water Resource Systems

MP is focusing on extreme weather events leading to large scale/flash flooding.

Changes in Extremes

- MP and its regional WGs intend to suggest improvements in both weather and climate models through model evaluation of extreme events.
- The High Impact Weather (HIW) events sub-group under WG-AAM is focusing on high impact events from recent years for (i) case studies in terms of observations and forecasts, (ii) linking operational forecasts to decision making, (iii) how monsoon research can best support hazard mitigation and (iv) whether forecasting frameworks need to adjust to account for socio-economic /climate change.

Water and Energy Cycles

- MP and its regional WGs aim to improve weather and climate models, including their capability for studying the water and energy cycles through model evaluation studies (e.g., CMIP, DYAMOND).

Contributions to WCRP, Including the Light House Activities

- Activities of MP and WGs aim to improve weather and climate models, enabling the modeling study of weather and climate “Extremes”.
- High Impact Weather (HIW) events sub-group under WG-AAM is focusing on high impact events from recent years during the monsoon seasons, which could lead to contributions to “Understanding High-Risk Events” LHA.
- There are some discussions in HIW sub-group under WG-AAM on how AI or Machine Learning could be used to enhance the warnings, and on the potential for involving social scientists to help understand public response to warnings. This could lead to contributions to “Digital Earth” LHA under "advanced digital technology".
- Masilin Gudoshava (WG-AFM) is actively involved in the “My Climate Risk” LHA.
- Izidine Pinto (WG-AFM) is actively involved in “Safe Landing Climates” LHA.
- Annalisa Cherchi (MP) is a member of GPEX Interim SSC.
- Most members of the eastern Africa subgroup of WG-AFM are involved in EPESC LHA’s "Africa Case Study" focusing on modeling the Eastern African rainfall.

Other Key Science Questions

List 1–3 suggestions that you anticipate your community would want to tackle in the next 5–10 years within the context of a land-atmosphere project

- How realistic are the high-resolution simulations of extreme rainfall events compared to the observations? How can we improve the model predictions of monsoon rainfall and associated extreme events?
- How does land surface temperature (LST) over global high mountain regions (including the Himalayas, Rocky Mountains, Andes mountains and other high mountains) affect the global monsoon precipitation at S2S scales?

Cooperation with Other WCRP Projects, Outside Bodies and Links to Applications:

APARC, S2S Prediction Project

- MP is engaged in interactions with APARC on the role of atmospheric composition in processes relevant for the monsoons, including the Atmospheric Composition and Asian Monsoon (ACAM) activity of APARC (https://www.sparc-climate.org/activities/asian-monsoon/).

- IMPO (project office of MP) personnel provides wiki page support for regional activities of S2S in South Asia.

CLIVAR

- MP will get involved with CLIVAR's Pacific Region Panel and OMDP (Ocean Model Development Panel) to improve the ENSO teleconnections in models.
- MP will get involved in the "**SynObs** Project" supported by CLIVAR for the evaluation of Ocean Observing System.

Contributions to the GEWEX Science Goals and plans to include these

Goal # 1 (GS1): Determine the extent to which Earth's water cycle can be predicted. This Goal is framed around making quantitative progress on three related areas posed in terms of the following questions:

1. **Reservoirs:**

What is the rate of expansion of the fast reservoirs (atmosphere and land surfaces), what is its spatial character, what factors determine this and to what extent are these changes predictable?

….

2. **Flux exchanges:**

To what extent are the fluxes of water between Earth's main reservoirs changing and can these changes be predicted and if so on what time/space scale?

….

3. **Precipitation Extremes*:***

How will local rainfall and its extremes change under climate change across the regions of the world?

The High Impact Weather (HIW) events sub-group under WG-AAM is focusing on high impact events from recent years for (i) case studies in terms of observations and forecasts, (ii) linking operational forecasts to decision making, (iii) how monsoon research can best support hazard mitigation and (iv) whether forecasting frameworks need to adjust to account for socio-economic /climate change.

Goal # 2 (GS2): 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:

1. **Forcing-feedback understanding:**

How can we improve the understanding of climate forcings and feedbacks formed by energy, water and carbon exchanges?

….

2. **ABL process representation:**

To what extent are the properties of the atmospheric boundary layer (ABL) defined by sensible and latent energy and water exchanges at the Earth's surface versus within the atmosphere (i.e., horizontal advection and ABL-free atmosphere exchanges)?

….

3. **Understanding Circulation controls:**

To what extent are exchanges between water, energy and carbon determined by the large-scale circulations of the atmosphere and oceans?

….

4. **Land-atmosphere interactions:**

How can we improve the understanding of the role of land surface-atmospheric interactions in the water, energy and carbon budgets across spatiotemporal scales?

….

Goal # 3 (GS3): Quantify anthropogenic influences on the water cycle and our ability to understand and predict changes to Earth's water cycle.

1. **Anthropogenic forcing of continental scale water availability:**

To what extent has the changing greenhouse effect modified the water cycle over different regions and continents?

….

2. **Water management influences:**

To what extent do water management practices and land use change (e.g., deforestation) modify the water cycle on regional to global scales?

….

3. **Variability and trends of water availability:**

How do water & land use and climate change affect the variability (including extremes) of the regional and continental water cycle?

….

2.5.1. CLIVAR/GEWEX Monsoons Panel Rapporteurs Report

Panel: CLIVAR/GEWEX Monsoon Panel

Rapporteur(s): Benjamin Lamptey, Jan Polcher and Xubin Zeng

Adherence to GEWEX and Panel's objective(s)

Plans to contribute to GEWEX Science Goal (GS1): Determine the extent to which Earth's water cycle can be predicted. The specific approach is to investigate

- Reserviors - the rate of expansion of the fast reservoirs (atmosphere and land surfaces) and the extent to which they are predictable
- Flux exchanges - the extent to which the fluxes of water between Earth's main reservoirs are changing and whether these changes can be predicted
- Precipitation Extremes - how local rainfall and its extremes change under climate change across the regions of the world – Already addressing this in the Asia- Australian Working Group
- *Note Monsoon Panel is addressing a) and b) by trying to improve the prediction of rainfall in world Monsoon regions
- The West African Sub-group of WG-AfM is looking at the GEWEX/GASS DYAMOND high resolution model outputs to see how the model represents the mesoscale convective systems in the area and how they affect the monsoon.

Achievement of annual goals for this reporting period

- All the three Working groups (Asia-Australian, AAM, African, AfM and American, AMM) are all functional. However, AMM WG activities need to be accelerated.
- Cross-Panel activities have been initiated – mostly with CLIVAR panels
- African Working Group is revising a paper on "Climate Modelling of precipitation over Africa"
- Asia-Australia Working Group is drafting a paper that will describe the skill of Subseasonal to Seasonal predictions and bottlenecks, and why teleconnections to Nino SSTs are poor (Monsoon processes and teleconnections sub-group).

Major accomplishments and results in reporting period

Organized four Scientific Capacity Building and Career Support activities (Webinars) as follows:

- Global Monsoon –13th September 2023
- Asian-Australian Monsoon – 30th November 2023
- African Monsoons – 6th March, 2024
- American Monsoons – 24th April, 2024

Drafting several reports

- Five (5) articles were published in 2023.

Arisen or noted science issues

- Asia-Australian Working Group is working to define monsoon index for South East Asia Monsoon

- How realistic are the high-resolution simulations of extreme rainfall events compared to the observation? How can model predictions of monsoon rainfall and associated extreme events be improved?

Emerging Science

- How does land surface temperature (LST) over global high mountain regions (including the Himalayas, Rocky Mountains, Andes mountains and other high mountains) affect the global monsoon precipitation at S2S scales?

Future plans

- To formulate at one project to address bottlenecks in simulation and prediction of Monsoon rainfall by involving GEWEX, CLIVAR and CliC
- Asian-Australian Working Group aims to publish results of work from past two years.

Recommendations to Panel

- Enhance the interactions with the other GEWEX Panels
- Do the basic science in addition to promoting the science in the various Working groups. Think about Pan Monsoon Panel research projects
- Do not only document and report the interaction related to research to operations activities. Together with the operational community, work out how to operationalize the activities.
- Panel should interact more with other sectors like agriculture, hydrology, health, among others

Considerations for SSG

- Promote interaction of GEWEX Panel co-chairs with Monsoon Panel
- SSG should request quarterly briefs (one-pager) from GEWEX and Monsoon Panel co-chairs specifically on interaction between Panels (i.e., structured communication)

Additional Remarks

Mosoon Panel can organize studies on:

- Why Coupled Models overestimate ENSO-Monsoon Relation (linkages across scales and physical processes)
- Why 2022/2023 Monsoons were very peculiar (process studies coordinated with modeling activities)

Annex 1 - List of Participants

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Annex 2 – Meeting Agenda

Monday 22 April 2024				
Time			**Panel Presentations - Overview and Plans**	**Presenter**
08:15	–	08:30	Welcome	
08:30	–	10:00	GHP – GEWEX Hydroclimatology Panel	Paola ARIAS, Alireza NAZEMI
10:00	–	10:30	Break	
10:30	–	12:00	GASS – Global Atmospheric System Studies Panel	Sandrine BONY
12:00	–	13:30	Lunch	
13:30	–	15:00	GLASS – Global Land-Atmosphere System Study Panel	Anne VERHOEF, Nate CHANEY
15:00	–	15:30	Break	
15:30	–	17:00	CLIVAR/GEWEX Monsoon Panel	Surya Rao ANGULURI
17:00	–	17:30	WWRP – World Weather Research Programme	Chris DAVIS

Tuesday 23 April 2024				
Time			**Panel Presentations - Continued & External Relations**	**Presenter**
09:00	–	09:30	World Climate Research Programme (WCRP) – Joint Scientific Committee (JSC)	Hindumathi PALANISAMY
09:30	–	10:00	World Meteorological Organization (WMO) – WCRP Secretariat	Hindumathi PALANISAMY
10:00	–	10:15	Cycles	Jan POLCHER
10:15	–	10:30	Global Precipitation Experiment (GPEX)	Xubin ZENG
10:30	–	11:00	Break	
			External Interactions	
11:00	–	11:20	Japanese Aerospace Exploration Agency (JAXA)	Tadahiro HAYASAKA
11:20	–	11:40	RIfS – Regional Information for Society CORDEX – Coordinated Regional Climate Downscaling Experiment	Prerecorded presentation
11:40	–	12:00	WMO-Hydrology	Stefan UHLENBROOK (Remote)
12:00	–	12:30	CLIVAR – Climate and Ocean Variability, Predictability and Change	Prerecorded presentation
12:30	–	14:00	Lunch	
14:00	–	14:20	APARC – Atm. Processes And their Role in Climate	TBC

Tuesday 23 April 2024 (continued)				
Time			**Panel Presentations - Continued & External Relations**	**Presenter**
14:20	–	15:00	GEWEX Open Science Conference Update	Peter VAN OEVELEN
15:00	–	15:30	Break	
15:30	–	17:00	GDAP – GEWEX Data and Analysis Panel	Hiro MASUNAGA

Wednesday 24 April 2024				
Time			**Agency Updates**	**Presenter**
09:00	–	09:20	National Aeronautics and Space Administration (NASA)	Craig FERGUSON
09:20	–	09:40	National Oceanic and Atmospheric Administration (NOAA)	Virginia SELZ
09:40	–	10:00	European Space Agency (ESA)	Diego FERNANDEZ
10:00	–	10:20	ECMWF	Richard FORBES
10:20	–	11:00	Break	
11:00	–	11:20	EUMETSAT	Joerg SCHULZ
11:20		11:40	ESMO - Earth System Modeling and Observations	Joerg SCHULZ
12:00	–	11:40	COPERNICUS	Carlo BUONTEMPO (Remote)
12:00	–	12:20	Centre National d'Etudes Spatiales (CNES)	Delphine LEROUX (Remote)
12:20	–	14:00	Lunch	
14:00	–	21:30	Afternoon and Evening Team Building Program	

Thursday 25 April 2024				
Time			**Strategic Panning continued**	**Presenter**
09:00	–	09:40	Activities Review	Xubin ZENG, Jan POLCHER
09:40	–	10:00	CLiC – Climate and Cryosphere	Edward HANNA
10:00	–	10:30	Break	
10:30	–	12:30	Local Presentation // PANNEX	
10:30	–	10:40	Overview of HungaroMet	Eszter Lábó-Szappanos
10:40	–	10:50	Ongoing research at HungaroMet	Gabriella Szépszó
10:50	–	11:20	Use of satellite soil wetness data in surface data assimilation of AROME/HU model	Helga Tóth
11:20	–	12:00	Recent advances in PannEx	Rita Pongrácz
12:00	–	12:30	Long term changes of the sub-daily precipitation extremes in the PannEx region	Mónika Lakatos
12:30	–	14:00	Lunch	
10:40	–	10:50	GEWEX Strategic Direction and Activities	Xubin ZENG, Jan POLCHER

Thursday 25 April 2024 (continued)				
Time			**Strategic Panning continued**	**Presenter**
15:00	–	15:30	Break	
15:30	–	16:00	Any Other Topics/Ambassadors/Awards	Jan POLCHER, Xubin ZENG
16:00	–	17:00	Summary Action Items and Recommendations	Peter VAN OEVELEN
17:00	–	17:30	International GEWEX Project Office Update	Peter VAN OEVELEN

Friday 26 April 2024				
Time			**Rapporteur Rapports**	**Presenter**
09:00	–	09:30	GASS – Global Atmospheric System Studies Panel	Ruby LEUNG, Gavin SCHMIDT
09:30	–	10:00	GDAP – GEWEX Data and Analysis Panel	Suzanne CREWELL, Bob SU
10:00	–	10:30	Break	
10:30	–	11:00	GLASS – Global Land-Atmosphere System Study	Martin BEST, Richard FORBES
11:00	–	11:30	GHP – GEWEX Hydroclimatology Panel	Qingyun DUAN, Li JIA
11:30	–	12:00	CLIVAR/GEWEX Monsoon Panel	Ben LAMPTEY, Xubin ZENG, Jan POLCHER
12:00	–	12:30	Wrap Up	Peter VAN OEVELEN, Xubin ZENG, Jan POLCHER
12:30	–	14:00	Lunch	

Annex 3 - Acronyms

The complete list of abbreviations and acronyms can be found at https://www.gewex.org/abbreviations-acronyms/