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Global Energy and Water Exchanges (GEWEX) Project
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Impressum

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[1]GEWEX Panels

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GDAP: GEWEX Data and Analysis Panel

GHP : GEWEX Hydroclimatology Panel

GLASS: Global Land-Atmosphere System Studies Panel

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Executive Summary

This report documents the proceedings of the 37th 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 Co-Chairs of the GEWEX Panels. This year's annual meeting was hosted by the Victoria University of Wellington and Institute of Geological and Nuclear Sciences (GNS) in Wellington, New Zealand, and took place from Monday to Friday, 10–14 February 2025.

During this session of the GEWEX SSG, participants reviewed the progress made by GEWEX and its four Panels throughout 2024, assessing the program's relevance to current and future global challenges. Each of the four Panels reported on a range of activities undertaken in 2024, which included the onboarding of new Panel members, updates of ongoing projects, initiation of new projects, development and marketing of various scientific products and the organization of both virtual and in-person meetings and workshops. The Panel 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 deliberations on existing or possible obstacles resulted in new action items and recommendations. In this context, the future of the International GEWEX Project Office (IGPO) was also discussed as the current funding situation has become opaque.

This year's SSG session also saw the third selection for the GEWEX Ambassadors Awards. This award has been created to honor colleagues who have contributed a significant amount of their time and energy to GEWEX and who can continue to promote GEWEX in the broadest sense, e.g., encourage other colleagues to be part of the GEWEX community, keep funders and stakeholders abreast of the latest developments when opportunity arises and represent the GEWEX community at selected events.

Part of this SSG session was reserved for presentations of research activities of our hosts, the Victoria University of Wellington and GNS. Discussions on areas of collaboration with GEWEX activities may lead to the formation of a potential Regional Hydroclimate Project, possibly jointly with parties in Australia.

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

In 2024, the support required to meet the obligations and responsibilities of the 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 2024 and includes the major items and recommendations from the 37th Session of the GEWEX Scientific Steering Group (SSG-37).

The GEWEX SSG-37, hosted by the Victoria University of Wellington and Institute of Geological and Nuclear Sciences (GNS), took place in Wellington, New Zealand, from Monday to Friday, 10–14 February 2025. The presentations and discussions of the meeting participants (Image 1) focused on:

- developments of the GEWEX Panels over the past period and goals for this 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)
- looking back to the GEWEX Open Science Conference jointly organized with Hokkaido University and the Science Council of Japan, held in July 2024 in Sapporo, Japan
- collaboration with GEWEX partners
- presentations and discussions with scientist from our hosts, GNS and Victoria University of Wellington, and
- other SSG business, including selection of the 2025 GEWEX Ambassadors and outlook for the International GEWEX Project Office.

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 supervised by 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 the relevant annual Panel report in §2.

Development, plans and possible and/or existing areas for cooperation 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-37 can be found in Annex 1 and the agenda of the SSG-37 in Annex 2

Image 1: GEWEX SSG-37 meeting participants

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 Joint Scientific Committee (JSC). The GEWEX SSG consists of two Co-Chairs and 11 panel members, four GEWEX Ambassadors and ex-officio members from the 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 (Fig. 1). 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).

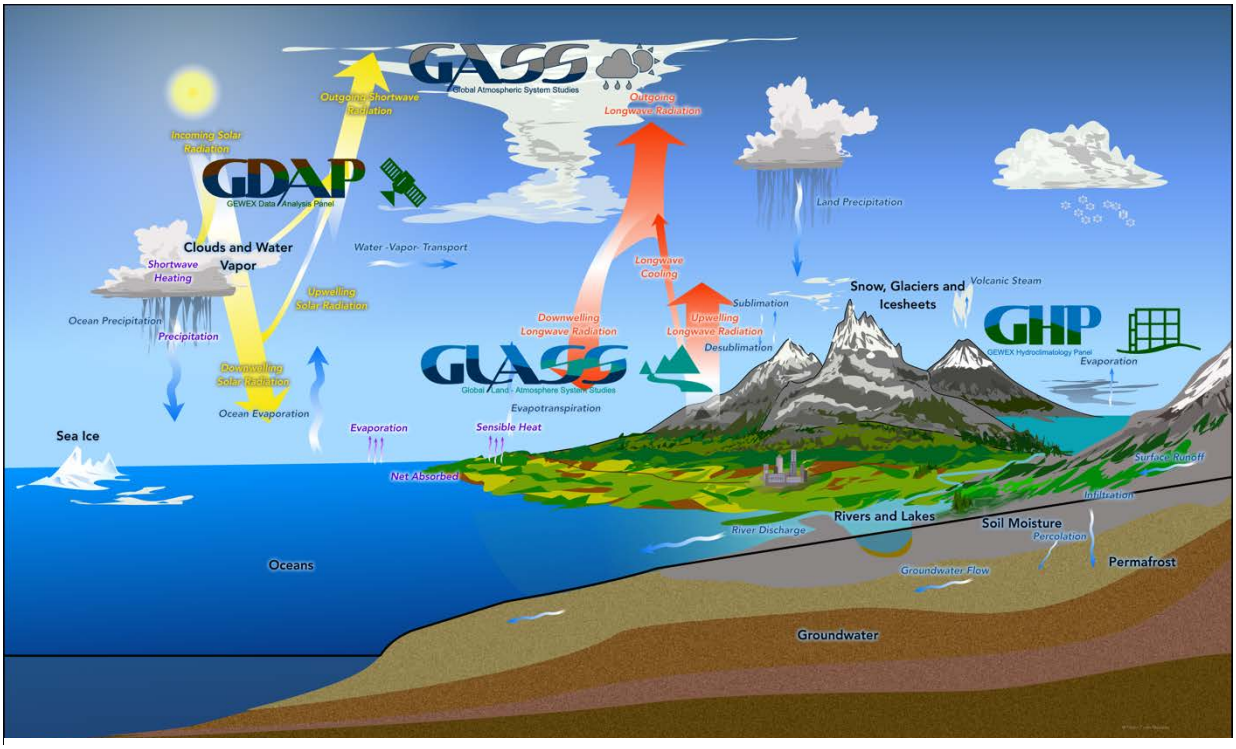

Fig. 1: The focus of the four GEWEX Panels in relation to the global and regional water and energy cycles (© P. van Oevelen, 2020)

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.

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 2024, 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 four 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 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, 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.

3. **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:
   - Regional Hydroclimate Projects (RHPs), an essential tool in understanding and predicting hydroclimates as they bring together various disciplines on water-related issues
   - 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
   - Global Data Centers collect and distribute important hydrology-related data
   - 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.

4. **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.

5. **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.

Below are points of attention and discussion raised during the Panel presentations.

General

- Panels and projects are advised to have a back-up plan in place for when a co-chair steps down and a successor is not immediately available.
- Volunteering works for a certain period of time. A funding basis is desirable when aiming for longevity of a working group or project.
- Start a discussion about the desired number of activities within each Panel. Too many or too few activities can have disadvantages.
- Analyze the economic and human life costs stemming from extreme weather events and compare these expenses with the costs of investing in research to enhance weather forecasting. Improved predictions could mitigate the impacts of such severe conditions.
- Prepare a flow chart with the GEWEX Science Objectives and GEWEX Activities to show how each interconnect and what is missing. Make cross-Panel activities visible on the GEWEX website. In this context, the 'determining EvapoTranspiration' (dET) crosscutting activity that currently resides under GHP is exemplary for collaborative efforts across all four Panels, not only from a measurement and monitoring point of view, but also from a process understanding point of view. dET has the capacity and opportunity to evolve as a process evaluation study. It is advised to revisit the guidelines put together during the first meetings and workshops. GDAP jointly with the dET CC working group could consider doing an assessment of the various satellite derived

evapotranspiration to get this process started. A GEWEX SSG member will take the initiative to organize an online meeting with GLASS, GDAP and GHP co-chairs.

- The annual report template could benefit from structural streamlining, elimination of redundancy and enhanced readability. Additionally, add a section to allow for Panel members' response to previous rapporteurs' report. In this context, also asking for a fact sheet with main (scientific) advances from each activity has been mentioned.
- Continue to involve model developers, in particular those working at operational centers, to see the benefits across resolutions. Consider gaps between observations and models. In addition, keep paying attention to, and improve low resolution models, as this will improve process understanding.
- Provide opportunities and/or create a mechanism that brings people from the various Panel projects and communities together to discuss ideas and opportunities for cross-Panel activities. In this context, a three-stage method is proposed to balance the Panel focus areas suggested by the SSG while maintaining the bottom-up approach within Panels and across Panels at the same time (Fig. 2).

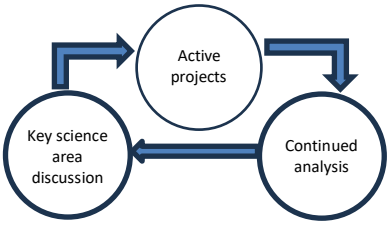

Fig. 2: Three stage project cycle

- How can GEWEX support WMO reporting to stimulate cross-program activities?
- Panel liaisons should be GEWEX-wide and not only within Panels. Knowledge and understanding of the general structure of GEWEX is essential to be able to fulfil this role effectively. One of the main tasks of a liaison is to actively establish cross Panel connections. To enhance cross-Panel collaboration, it's proposed that former co-chairs and/or the SSG rapporteur could be invited to participate in Panel meetings. Moreover, synchronizing the scheduling and location of Panel meetings to include a shared day filled with joint activities and discussions is another strategic approach to strengthen cross-Panel communication and collaboration. In this context, a three-year cycle is proposed with organizing a Pan-GEWEX meeting every three years and co-locating two Panels in the intervening years. Another suggestion is to have one or more Panel members participate in the SSG-meeting.
- The Pan-GLASS Conference will take place in 2026 and the Pan-GASS conference is scheduled for 2027. The Pan-GHP conference is also scheduled for 2027, and potential hosts could include RHPs Baltic Earth, Third Pole Environment-Water Sustainability (TPE-WS) or Asian Precipitation Experiment (AsiaPEX).

GASS

GASS is advised to consider:

- consolidating projects that show major overlap. This is expected to benefit the overall interaction and performance of the project, as it attracts people from different communities with diverse expertise to one project rather than having them spread across multiple projects
- Exploring opportunities to leverage Artificial Intelligence (AI) and Machine Learning towards achieving GASS science goals or facilitating/coordinating community activities in atmospheric and Earth sciences.
- promoting and increasing the utilization of observational data related to convection from field campaigns that have taken place in the Global South, e.g., Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations (RELAMPAGO)
- rethinking the way it conducts business, as GASS projects seem to be mostly working individually. Collaboration and linking with other Panels and groups might improve the impact and effectiveness of the projects. The Impact of Initialized Land Temperature and Snowpack on Sub-Seasonal to Seasonal Prediction (LS4P) project is, for instance, ideally suited to interact with other Panels. Now might also be an opportune time for interaction between GASS and the Multi-scale Transport and

Exchange processes in the Atmosphere over Mountains – programme and experiment (TEAMx) CC on high mountain regimes, as TEAMx has concluded its observation period and is entering its modeling phase

- collaborating with GLASS on i) the dynamics of turbulent transfer of heat and latent heat from land to atmosphere and its timing, which drives nocturnal convection, and ii) linking soil parameterizations to convection

GDAP

GDAP has assessed necessary fundamental data and made it available to the community. The increasing number of inactive stations in the Baseline Surface Radiation Network (BSRN) is of concern. BSRN is a recognized network of the Global Climate Observing System (GCOS). However, GCOS is not active in bringing this network to the attention of its community. It is important that representatives from leading weather agencies around the world, such as the European Centre for Medium-range Weather Forecasts (ECMWF), highlight the importance of BSRN and climate data centers in general in their communities. The GDAP proposal is to assess in the form of a report or a publication how BSRN data is used and how it serves Numerical Weather Prediction climate research and then to convey this message by visiting the operational stations with the assistance of WMO.

Of great concern is also the lack of continuity of the microwave constellation for precipitation measurements and the LIBRA (NASA) mission to monitor Earth's radiation Budget. GEWEX should take back stewardship and strengthen its role of representative of the research community and produce a statement to make the community aware that some type of Sentinel mission is needed as this concerns critical measurements.

Advocacy outside the SSG-37 participant group and the satellite group is important. Below are the four lines of actions that are proposed.

1. Document who is actually accessing and using the radiation and precipitation data sets as it will help to further strategize the plan of action.
2. Highlight the relevance and importance of data to modeling and modeling centers.
3. Reconnect and be more involved with space agencies other than the National Aeronautics and Space Administration (NASA), such as the European Space Agency (ESA), Japanese Aerospace Exploration Agency (JAXA) and China National Space Administration (CNSA), in terms of satellite missions and developments.
4. Write a global opinion paper related to satellite missions beyond a response to the NASA decadal review in 2024 only.

Other points of attention related to the GDAP presentation are listed below.

- Although the current reporting period saw several changes in the GDAP membership, more geographical variation is needed. In addition, there is an opening on the panel for a representative of the global ground-based radar network.
- Consider a GDAP-GLASS cross Panel CC activity on land surface temperature.
- Make sure that the working groups focusing on convection/cloud tracking are connected to the modeling community. Tracking is a way to simplify the richness of satellite data. Machine learning can also be engaged in these efforts.

GHP

GHP is advised to consider:

- merging the River Experiment (RivEX) CC and GEWEX Global Groundwater Network (GGN) as they are closely related, although each focuses on specific processes
- forming a strategy on how to bring the Floods, RivEX and determining Evapotranspiration CCs together and connect with the land surface modeling community in GLASS
- encouraging CCs to connect with relevant RHPs. RHPs will create a natural structure within which they can bring the different CCs together.
- RHPs providing comprehensive observational records for extreme events that comprise a testbed for the international modeling community now that RHP's turn towards an impact focus
- how to get the MOUNTerrain CC off the ground
- how to effectively synthesize and transfer scientific learnings gained from its diverse groups and activities to advance its core objectives
- finding a mechanism for activities to learn from each other.

Despite many efforts, no starting point has been found for a new activity in Africa. The focus may have to shift to a less demanding activity, such as setting up a network for early career scientists in Africa. Contacting members of the four CORDEX Africa working groups is another option to pursue.

GLASS

A GASS-GLASS webinar will be organized to establish a cross-Panel interaction on the GEWEX Atmospheric Boundary Layer Study (GABLS) project. GLASS is advised to consider to:

- (re)connect with WCRP's Core Project Earth System Modelling and Observations (ESMO) and WMO's Working Group on Numerical Experimentation (WGNE)
- promote the engagement on addressing:
  - fluxes of carbon
  - turbulence parameterization
  - urban land surface and fluxes
- link the three GLASS pillars to GEWEX objectives

In the past, the Flux Net communities Ameriflux and the Integrated Land Ecosystem-Atmospheric Processes Study (ILEAPS) were not open to working with GEWEX to make data available that could be used to develop land-atmosphere interaction parameterizations correctly in models. The JSC-Liaison and GLASS Panel co-chairs will approach them again, including the National Ecological Observatory Network (NEON).

The following items were discussed with regard to the GEWEX Land/Atmosphere Feedback Observatory (GLAFO) project.

- Could be made central to GLASS activities and become a resource to anyone who wants to do a modeling project. Currently, all GLAFO sites have standard observation capabilities. Would it be possible to add additional instruments based on the project requirements?
- It would be beneficial if monsoon and other regions that are having difficulties raising the necessary funds for the development and maintenance of a GLAFO site could be supported by the United Nation Special Observations Financial Facility (SOFF) Fund co-created by WMO.
- Obtaining good quality, high resolution ancillaries for models needs attention

- The UK Met Office is planning a benchmarking workshop with the aim to develop an international benchmarking standard for land models. This might be turned into a GEWEX workshop.
- The importance of and need to focus on heterogeneous exchanges between land and atmosphere has to be emphasized. The cost of the impact of weather in terms of money and lives is high, especially in cases of extreme weather of which 90% is land-based. Currently, there exists a disconnect between the relevance and value of terrestrial processes. Therefore, a change of our focus is required. The reason why research communities cannot get the land part correctly in models is a problem of external organizations. Showing what the economic cost of this lacking is, might lead to additional funding.
- Discuss which format to use to make data easily accessible over all stations; for instance, the Observations for Model Intercomparison Projects (Obs4MIP) or Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS).

Monsoon Panel

The CLIVAR/GEWEX Monsoon Panel is advised to consider:

- making observations part of the Panel's objectives
- collaborating and participating in the AsiaPEX RHP to the extent that political issues permit
- connecting with projects in the different GEWEX Panels in general
- encouraging field campaigns in South America
- connecting with communities outside the MP's working groups
- the global nature of monsoons and bringing the regional working groups together.

A separate call will be organized with the Monsoon Panel co-chairs to discuss the rapporteurs' report.

The 9th GEWEX Open Science Conference (OSC), held in Sapporo, Japan, in July 2024, brought together a diverse global community. With 1300 participants from 45 countries, including 900 scientists and 400 representatives from government agencies and private sector, the conference went beyond being a major academic meeting (Image 2). Co-organized by Hokkaido University and the Science Council of Japan, the event provided a comprehensive platform for interdisciplinary dialogue on scientific research, policy development, and societal implications.

The 12 stakeholder sessions, held over the course of four days, were a significant feature of the conference, where the latest research in energy-water cycles, climate change and their societal implications was shared and discussed among researchers and policymakers.

Image 2: Participants of the 9th GEWEX Open Science Conference, Sapporo, Japan, July 2024

One key outcome of the stakeholder sessions was the formulation of a joint statement reflecting the consensus of seven Japanese Ministries on:

- intensifying collaboration among stakeholders, including government agencies
- the importance of dialogue and shared vision between policy makers and academia linking scientific findings with policy measures, and
- strengthening the public-private academic partnership to advance climate and water research.

The stakeholder sessions at the OSC have also led to the organization of the Hokkaido Climate Change Impacts Research Symposium, co-hosted by various government agencies and the Hokkaido Climate Change Adaptation Centre. Keynote speeches were related to meteorological and hydrological forecasting, flood control and disaster prevention.

Outcomes of the stakeholder session have also initiated the coordination of the third phase of the Japan-The Netherlands joint research project for a risk assessment method based on ensemble climate information in the European region, including the mid-mountainous areas near the German-Belgian border.

In conclusion, the international cooperation and joint research promoted at the GEWEX OSC contribute not only to the advancement of science but also to the development of prediction and monitoring technologies for global and regional climate change. It showed that scientific knowledge and policy can and should work in tandem.

Since 2022, WMO has been compiling the State of the Global Water Resources report to deliver an extensive overview of global freshwater resources. This report emphasizes how climate change and human activities affect water availability. The first report over 2023 was released in October 2024. Encouragingly, more countries are now participating, providing data on variables such as river discharge and groundwater. However, the available data remains insufficient, with gaps notably in water usage and management details. This hinders efforts to assess energy imbalances and determine unexpected variations in water distribution.

GEWEX has been invited to contribute to this effort and suggests conducting a water assessment. By contrasting natural models with real-world data, insights into water usage might be derived. GEWEX encourages using both hydrological and land surface models to gather comprehensive information on energy, water, and carbon cycles. Such approaches can enhance understanding and reduce uncertainties. Additionally, discussions included among others using machine learning and meteorological analysis. GEWEX's support to WMO could assist in improving the assessment of water resources, provide estimates from unmonitored patterns, and accelerate the report's publication timeline from previous years.

An exploration of the wishes of the meeting participants for future GEWEX activities resulted in the following suggestions:

- projects in specific areas:
  - interface between high-resolution satellite measurements and the global storm resolving model community
  - linking radiation energy with the water cycle
  - imbed human water management processes in land surface models and couple with atmospheric monitoring
- collaboration or joint projects with:

    - various WMO and WCRP activities, including the funds to do so, e.g., a GEWEX-APARC project around stratosphere, troposphere coupling and its role in organized convection with observations and models
    - Commercial satellite organizations
- promotion outside the scientific community of
    - GEWEX activities, including cross-Panel activities
    - the importance of science; think more in terms of trade-offs
- data/observations/networks:
    - create a data net of ground-based radar by bringing the world ground-radar producers together
    - greenhouse gas monitoring, as it is important for controlling the water and energy cycles
    - stronger support in reference networks supported by operational centers
    - systematic guidance about the use of different observational products compared with various modeling products, including common mistakes
    - streamline data processes, understanding modeling studies in a causal attribution and impact study
    - look for opportunistic data and new data sources and form ideas how they can be useful, like radar data for precipitation and commercial microwave links
- taking the lead on the societal assessment of societal challenges for survival
- continue to attract and recruit early career researchers for Panel and/or project membership to keep GEWEX vibrant and make sure to maintain the GEWEX spirit of collaboration over competition.

At this year's SSG meeting, the first Ambassador's corner was introduced where participating GEWEX Ambassadors were asked to give a presentation on a subject of their choosing. GEWEX Ambassador Andy Pitman's presentation titled "Drought: possible lessons from Australia" covered causes of droughts in Australia, drought metrics, effects of droughts and a number of takeaways like the importance of sharing evaluation tools and that models need to be analyzed across the entire workflow.

GEWEX Ambassador Mike Ek's presentation covered GEWEX contributions to improving Earth System Models (ESMs). ESMs for weather and climate are increasingly complex, with many processes and interactions. GEWEX provides focus to examine and understand Earth system processes and interactions via GEWEX projects and activities, where groups work collaboratively using state-of-the-science data sets and ESMs and ESM components like land and the planetary boundary layer. GEWEX has enabled Hierarchical System Development (HSD), which is an efficient model development "systems engineering" approach, spanning simple to complex. HSD can help improve the understanding of spatial and temporal dependencies using efficient software infrastructures to connect HSD steps with verification and diagnostic systems to evaluate ESMs and their components.

The future of the funding of the IGPO in 2025 remains uncertain due to political sentiments in the United States. In the event that NASA does not renew its support, alternative sponsors will need to be identified to ensure the continuation of the GEWEX Panel activities and the preservation of the 30+ -year history of the GEWEX community. One proposed approach to enhance IGPO resilience involves integrating two young officers into the team. Building on the success of the 9th GEWEX Open Science Conference in Japan, the suggestion is to allocate one officer to Asia, with a focus on stakeholder engagement, specifically starting in Japan. The second officer is recommended to be based in Europe, especially since the European GEWEX SSG co-chair will be stepping down by the end of 2025. Given the

current high level of interest in this field, it is also preferred that this officer possess a strong background in satellite observations to facilitate collaboration with European space agencies.

Exploratory and informal discussions have shown that the European Space Agency (ESA) is willing to fund 0.5 full-time equivalents from 2026 onwards. The European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) is interested in an officer to coordinate the various Satellite Application Facilities (SAFs). This would directly interface with GDAP activities and can also link to other GEWEX Panels. A job description needs to be written together with the agencies.

Note that the above strategy is not limited to these regions. If there is interest elsewhere, it is advised to explore this further.

In light of the foregoing, the following questions arose: 1) what would be missed if GEWEX's continuity were to be broken? 2) what efforts could be undertaken to prevent this? and 3) what should GEWEX focus on? Each participant gave her or his view on these questions, which can be summarized as follows.

GEWEX is an independent voice, representing a large community of researchers across borders that advocates for certain aspects regarding the energy and water cycle. It is an international community platform where people voluntarily invest time and knowledge in order to collaborate with others. A lot of the interdisciplinary work and interfacing between observations and models would not be done as effectively without it. GEWEX activities have a leading role in science relating to the water and energy cycle by bridging scales and connecting certain sectors, for instance, within the modeling community and the space agencies. In general, GEWEX has improved process level understanding of atmospheric physics and interactions. It is especially the sum of all the work and activities in GEWEX that come together and address major issues that makes a difference. In this coordinating role, GEWEX improves the efficiency and effectiveness of alignment and planning of research.

By listening to the wishes and needs of society and the research community, GEWEX should continue to focus on fundamental work and new science, such as a project on the impact of renewable energy on climate change. Funding and diversification of funding could be increased by linking water impacts to economic costs.

1.2 GEWEX Links to WMO, WCRP and WCRP Core Projects

At the 37th session of the GEWEX SSG, representatives from various WMO and WCRP groups provided updates on their ongoing work and explored potential collaborations with GEWEX. Tim Naish, recently named Chair of the WCRP Joint Scientific Committee, also introduced himself. He highlighted GEWEX as one of WCRP's most active and high-profile Core Projects. GEWEX's new strategic plan includes a clear vision for the future and is well aligned with the priorities that came out of the 2023 WCRP Open Science Conference in Kigali, Rwanda.

Founded in 1992, WCRP's Core Project *Stratosphere-troposphere Processes And their Role in Climate* (SPARC), changed its name in early 2024 to Atmosphere Processes And their Role in Climate (APARC) to better communicate and formalize its area of research in recent years.

There are many opportunities for APARC and GEWEX to work together. Collaboration with the GASS Panel is particularly encouraged, as both groups work with people in the same field of expertise and modeling centers. A point of attention is to be aware of the risk of introducing artificial barriers and

duplication. APARC representatives are invited to participate in the GASS and GDAP Panel meetings to establish those links of collaboration on a project level.

In August 2024 the SSG of WCRP's Core Project *Climate and Cryosphere* (CliC) approved the new working group *Impacts of Changes in the Mountain Cryosphere* (IC-MontC). The GEWEX RHP ANDEX was mentioned for possible collaboration on regional climate-glacier-hydrology work. However, there are various other GEWEX projects with a focus on mountainous hydrology, for instance INARCH, AsiaPEX and Global Water Futures (GWF). Concerns were raised that many similar activities are taking place within CliC and GEWEX. Points of discussion between CliC and GEWEX should include how coordination and collaboration between the various working groups can be improved. Of importance is that both Core Projects raise awareness in society about the contribution of glaciers to our water resources.

Another topic on which CliC and GEWEX, particularly with the GLASS Panel, can collaborate is the relaunch of an activity on snow processes in land surface models, with a focus on how snow is represented in the land part of global models. Currently, there are no glacial processes incorporated in land surface models. In this context, there is a project of the World Weather Research Programme (WWRP) aimed at flood forecasting, with an emphasis on the effect of rain on snow, as this can cause a lot of flooding. This process is not well understood, and the effects are hard to predict.

The presentation of WCRP's Core Project *Climate and Ocean – Variability, predictability, and Change* (CLIVAR) included an update on its organization and activities. CLIVAR's Research Foci address urgent and actionable research challenges and have a life span of three to five years. The current foci are:
i) Tropical Basin Interaction and ii) Marine Heatwaves in the Global Ocean. A proposal has been put forth to establish a third focus on the interaction between sea and continental hydrology. Coastal processes, crucial for societal welfare, are not adequately addressed by km-scale models and present an opportunity for collaboration between CLIVAR and GEWEX.

One of the more recent Core Projects of WCRP is the *Earth System Modeling and Observations* (ESMO) project. In early March 2024, the ESMO SSG convened for the first time. The organization of ESMO is grouped and strategized around data and aims to coordinate, advance, and facilitate all modeling, data assimilation and observational activities within WCRP. In order to improve and strengthen the links between ESMO and GEWEX, a proposal was made to organize a summit to discuss which links need to be established to maximize the efficiency and to prevent and minimize duplication of efforts between the two groups.

The Integrated Prediction of Precipitation and Hydrology for Early Actions (InPRHA) project, part of the World Weather Research Programme (WWRP), aims to enhance warning strategies for multi-hazard events impacting the water cycle over short time scales, ranging from minutes to days. Central to this recently-launched project is a commitment to integration across the entire value chain, embracing a transdisciplinary approach that combines precipitation and hydrologic predictions with insights from social sciences within a changing world. Currently, InPRHA is forming task teams, and it is recommended to include engineers in the project group, as infrastructure plays a critical role in short-term hazard responses.

Members of InPRHA are invited to participate in the 2025 GHP Meeting in Montreal, July 2025, to discuss synergies and links between the two groups. Several RHPs have transdisciplinary ambitions and could offer well-documented test cases with a geophysical side, for instance, the Global Water Futures RHP. Collaborative efforts may also address the attribution of extreme rainfall events concerning short-

term forecasts. Another area of exploration is the integration of high-resolution modeling with weather modeling to strengthen ties between GLASS, GHP, and InPRHA. This could potentially lead to an infrastructure that enables coupling of hydrological models to elements of land models. In addition, examining catchment hydrology through hydraulic conductivity and interactions between downstream flow and land surfaces, combined with involvement from the inundation community, may provide further beneficial insights.

WCRP's Lighthouse Activity (LHA) *Digital Earth* is a crosscutting activity designed to support and extend WCRP's Core Projects. The areas of activity can be summarized as:

- fully coupled km-scale regional and global models: foster a global research network in km-scale modeling of the Earth system and individual components
- data-fusion for climate: establish an active community for climate data assimilation and data driven modeling (e.g., Machine Learning/AI methods), expanding on numerical weather prediction and reanalysis
- beyond the physical Earth system: include human interactions on and impacts to human systems in Earth system models.

Collaboration with GEWEX can further improve on km-scale land-atmosphere interactions with the GLASS Panel. A lot of the fundamentals of how km-scale models are developed are not designed for km-scale land modeling. Currently, a lot of effort in the GLASS Panel is going into revisiting and rethinking lower atmosphere turbulence and how to use this in coupling. GLASS and ESMO are currently in discussion on how to set up a process that will specify how these new schemes, once developed by GLASS, can be implemented by ESMO. LHA Digital Earth should be included in these discussions, which can also be part of the conversation about forming a new working group. Another important aspect of the conversation should be how to draw attention to the need to put effort into land modeling.

Convection and convective organization are an issue with km-scale modeling. A proposal arose to revive the effort to form a working group with members of the GASS Panel on convective organization. GASS projects the *GEWEX Aerosol Precipitation* (GAP) initiative and the second phase of the *Diurnal Cycle Precipitation* (DCP) project both use km-scale resolution modeling.

Part of the discussion focused on making explicit the use of high-resolution models to improve lower-resolution models. This can be useful for several reasons.

In 2024, WCRP's LHA *Global Precipitation Experiment* (GPEX) established an interim SSG and appointed co-chairs for its four working groups. Numerous global precipitation products exist, and GDAP is at the forefront of evaluating them while advising the broader community. GPEX aims to identify anchor projects and establish connections with other WCRP precipitation-related activities. This effort ensures that their work complements existing initiatives rather than replicating or duplicating them, thereby enhancing the overall effectiveness and impact of precipitation research efforts globally.

Although GDAP is already looking into how the global products are able to reproduce aspects of rainfall, improving the definition of precipitation in terms of its characteristics (duration, frequency, intensity, type and quality) is of importance. Current precipitation models perform poorly in this area.

WCRP's LHA *Safe Landing Climates* (SLC) gave an overview of its ongoing and planned activities, including progress and results. All SLC's activities revolve around two main questions:

1. which risks of climate change and global scale hazards are the research community missing or need more attention? and
2. how to identify achievable pathways that are relatively safe and avoid compromising other sustainable development goals?

The following opportunities for collaboration with GEWEX were identified:

- participation in the water-related event that is currently being developed together with WCRP's LHA *My Climate Risk* (MCR) for the Convention of Parties (COP) 30 in Brazil. This will be an outreach activity to highlight what is happening with the water cycle in terms of extreme and shocking events in the world as part of a broader program associated with it
- joint organization of a seasonal school in Japan on Earth system models and water availability
- linking to economic modeling by connecting to economists on how to advance the representation of water as a variable in assessing the economics of future climate change.

SLC focuses on temperature as the main indicator of climate change. As temperatures rise, potential evapotranspiration increases, resulting in more water vapor in the atmosphere that is no longer available to society, increasing the risk of drying and droughts. Additionally, the increase of potential evapotranspiration will also result in changes in the nature of precipitation. Precipitation will be more in the form of intense and shorter burst, making the move of people to areas with rainfall not a viable option as this type of precipitation will lead to rising surface water, and with insufficient storage capacity of rivers, to flooding. Another compounding factor is that water management systems are aimed at achieving more evapotranspiration as it means a higher production of plants. The decreasing availability of fresh water flowing to the ocean in turn poses a threat for marine life.

Engineering systems always include safety margins that handle a certain amount of change. Is this margin quantifiable with respect to water management systems? Even if climate change were to be ignored, the world population is constantly changing, which means that there are almost continuous changes in the way water is being managed. It is therefore not possible to assume that the current situation is necessarily relevant to a future time.

In light of the above, GEWEX proposes that there should also be a Safe Landing for Water component. The water issue is different from that of temperature changes, because you have to consider both water usage and geophysical water quality. Weather and climate modeling should include not only the physical environment, but also all anthropogenic activities.

The ensuing discussion centered around the questions: i) what does Safe Landing mean, and how can we define this for water? and ii) can GEWEX provide the research community with some kind of metric that indicates to what point climate change is still safe for water's availability and manageability? Two extreme positions were given:

1. the only safe climate is the one for which our society was designed or has adapted to and
2. society can adapt to anything. It's only a matter of financial resources.

Society needs to be made aware of the global threat of climate risks in the context of water and to be motivated to act. Changes in the water cycle are likely to be a source of (future) conflict between countries in different parts of the world. There are many technological ways to deal with freshwater shortage, like desalination. How willing and able are we as an entire society to go in that direction? The concluding remark at the end of this discussion was "the work of GEWEX is super important".

WCRP's Core Project *Regional Information for Society* (RIfS) does not so much provide the information or the service to serve society, but rather researches how we can better provide information that is relevant to society. There is no one-size-fits-all answer to the question of what the best way is. In general, products and outputs are going to differ depending on the type and theme of the project. For instance, the goal of the working group on Robust Information is to produce some guidance documentation in terms of how to talk to decision makers, stakeholders and scientists.

The composition of the RIfS SSG currently relies heavily on members with a background in the natural sciences. Existing vacancies within the SSG will be filled by members with expertise in social learning.

RIfS has broad and far-reaching goals. It is spinning up a lot of projects and subprojects at the same time. There is a need to reflect on priority and objectives for some of these individual projects and how they differ from each other. As resources are limited, the thematical focal point and priority are on the collaboration with GHP's RHP ANDEX, a regional hydroclimate project for the Andes, and CORDEX Africa.

The 2024 award process for a research fellowship with a focus on Africa has been completed. The award went to the research proposal titled "*AI-Driven Framework for Integrating Advanced Hydrological Models to Optimize Water Resources Management in the Nile Basin*". Based on the research objective, the WCRP fellow will be given a warm welcome and will engage with the GHP community. Given the limited time and resources of the fellowship, the focus should be on identifying practical, actionable activities.

In February 2024, the launch of WCRP's LHA *Research on Climate Intervention* marked a step in the study of Carbon Dioxide Removal (CDR) and Solar Radiation Modification (SRM) methodologies. The primary focus of this initiative is to create a globally-inclusive research environment that addresses the scientific, ethical, and governance aspects of these climate intervention methodologies. Since the focus of the LHA is mainly on temperature, it is proposed that GEWEX can contribute by adding a water perspective based on the lessons learned from humanity's water intervention over the past 2000 years.

The United Nations (UN) is facing mounting pressure from member states to formalize its stance on climate intervention strategies. Due to its limited scientific expertise in this field, the UN Environment Programme has reached out to WMO for collaboration. In response, a two-day workshop, in partnership with the WCRP and the LHA Research on Climate Intervention, is scheduled for May 2025. This workshop will bring together WCRP experts, policymakers, and representatives from the private sector to address scientific gaps and ethical considerations related to SRM, enabling the UN to make informed decisions regarding climate intervention methods. The leadership of the WCRP views this collaborative effort as an opportunity to enhance visibility and maintain a neutral stance among UN member states.

Meeting participants have expressed caution to the above, noting that while the WCRP plays an important role in global science coordination, it is not a scientific assessment or science policy organization. Meeting participants have voiced strong reservations regarding the capacity of the WCRP to navigate the complex interactions between science and policy when it comes to climate intervention methodologies.

Concerns have also been raised about the potential pressure on the WCRP to make decisions beyond scientific boundaries and the inherent challenges of maintaining a purely scientific perspective. It is emphasized that climate models do not offer precise information at local to regional scales, and the

efficacy of climate intervention methods can vary significantly depending on the context in which they are applied. The complex interplay between science, policy, and geopolitics underscores the need for careful consideration of governance frameworks surrounding climate intervention activities. As this is a political issue, potential fall out if WCRP comes out with directions or recommendations is real. Moreover, in certain parts of the world, the word “climate” currently has a negative connotation and might impact research funding negatively.

On the specifics of climate intervention or geoengineering, the biggest issue is not the science, but governance, due to the reason that once initiated, climate intervention measures may pose challenges in terms of reversibility and long-term implications. The stakes are high, as the repercussions of starting and then halting such activities could be more severe than never engaging in them at all. Additionally, there is a concern about the moral hazards associated with climate intervention.

Trying to apply science to governance issues is fraught with danger. The research community does not have the expertise to answer the question of how to govern or assess such processes. It seems as if stakeholders are basing their questions on a misconceived notion about what scientists can add to the conversation of climate intervention.

The purpose of the new WMO Hydrology Research strategy is to accelerate research that improves the delivery and use of hydrologic data, information, and services and responds directly to the needs of national hydrological and meteorological service providers.

WMO/WCRP leadership dictates what is of importance and focuses its directives mainly on climate in terms of temperature change and the 1.5^{o} -threshold. However, the general public is especially interested in the impact of weather, particularly in the case of extreme events. It is therefore of interest that the operational centers are not informed of the importance of hydrology as part of the climate system and that they also need to get involved in hydrology forecasting. A complicating factor is that matters of the atmosphere are organized at a national level while water in its liquid form on the surface belongs to a catchment, which is mostly governed on a regional level.

One of the long-term ambitions of WMO Hydrology is that no one will be surprised by a flood, which is foremost an engineering hydrology problem. One of the essential needs of hydrologists to address this problem is excellent forecasting. In contrast, GEWEX is interested in the visible meteorological modeling and focuses on changes in the probability of a flood. Merging these two profoundly different approaches is going to be hard. One area where GEWEX could potentially exert influence is the annual report of water resources, as it is still controlled by WMO and not by national or regional water organizations.

There is also a disparity between the hydrology work mostly done in GEWEX and operational flood warning efforts. Currently, operational services are expanding into areas like seasonal stream flow forecasting, which is more aligned with GEWEX activities. The connection between WWRP Hydrology and GEWEX may be found in this time scale and the very short disaster warning.

By focusing on places where common needs and/or priorities exist and by sharing observational data, the integration of hydrological models in, for example, reanalysis is promoted and can accelerate progress.

In this context, GEWEX is asked to organize its next SSG meeting at WMO in Geneva, Switzerland, in combination with a workshop or a one-day event to bring together the different WMO departments already working on hydrology aspects. This opportunity could be used to inform them of the various

GEWEX activities and to formulate some concrete, tangible objectives for both sides to work on together.

1.3 GEWEX Partners and Sponsors

The presentations of our local hosts, Victoria University of Wellington and GNS Science, resulted in discussing the possibility of starting an RHP in New Zealand with a focus on groundwater. New Zealand has the financial and human resources, observatories, modeling capacity and a distinct hydrological landscape. A connection could be made with other WCRP climate activities.

The current GEWEX Global Groundwater group preferred to start as a GHP Network rather than a crosscutting activity. This Network prefers a bottom-up approach by first bringing together the geophysical and climate hydrology communities and moving forward based on the input. Each community has its own perspective on groundwater. In the end, this route will be more sustainable and will benefit the science.

The European Center For Medium-Range Weather Forecasts (ECMWF) is celebrating its 50th anniversary with several events at its locations throughout Europe. In December 2024, ECMWF's council approved the Strategy for the period 2025–2034. The main change is the increased emphasis on machine learning and AI in weather prediction. Of the many wide-ranging activities, the following were highlighted:

- improved physical model and data assimilation developments
- km-scale global prediction (Destination Earth Extremes and Climate Digital Twin)
- maximizing the use of observations
- Copernicus services: reanalysis (ECMWF Reanalysis 6, or ERA6), seasonal forecasting, atmospheric composition, increasing emphasis on the impact sector (river flow, urban, fires)

Earth Science in Action for Tomorrow's World , the new Earth observation strategy of the European Space Agency (ESA), was published in October 2024. It will be used to implement all of ESA's calls for Earth explorers. In addition, it also provides information about activities on the exploitation side of ESA, as it is moving towards "Science in Action". Science in Action involves the preparation of future missions and activities that ESA is trying to do in order to move from science into new services for citizens.

The new science strategy includes many open questions in the context of Earth system science and climate research. Many of these questions are grouped in a number of major pillars. Of interest to GEWEX are the two pillars concerning the water cycle and energy fluxes. Future calls for scientists to submit proposals for future missions will have to fit these categories. It is therefore expected that proposals addressing the water and energy cycles, which are of relevance to GEWEX, will increase.

The measurement of water that is intercepted by vegetation is not a specific aspect of an ESA mission. Although not well done yet, this might be a byproduct of, for example, evapotranspiration, as ESA is not only looking at evaporation but also at interception. However, if interception is an important aspect for the land-atmosphere interaction, this can be discussed with ESA to have it pay more attention to this feature.

An article on the Mass-change And Geosciences International Constellation (MAGIC), a joint NASA/ESA constellation concept, will be published in the coming Q2, 2025 edition of the *GEWEX Quarterly*.

GEWEX will participate with several sessions in the ESA Living Planet Symposium in Vienna, Austria, in June 2025.

Today's Earth is a global/regional land simulation for hydrological monitoring and forecasts of the Japanese Aerospace Exploration Agency (JAXA). Validation using ground-based observations in the United States will be done by the University of Tokyo in collaboration with JAXA. This group is already connected to GHP CC RivEX effort, which prepares modeling groups towards data assimilation of the Surface Water and Ocean Topography (SWOT) satellite mission.

The status of the idea to form a Water Constellation under the umbrella of the Committee on Earth Observation Satellites (CEOS), which would involve combining the water cycle instruments launched or planned by the various space agencies, is unknown. However, JAXA will continuously focus on water related themes for at least the next seven years. In this context, JAXA is currently developing a plan which, once finalized, can be shared at GEWEX meetings.

The US National Aeronautics and Space Administration (NASA) gave us an update on its relevant missions and programs and informed us on NASA's recent GEWEX-relevant calls for proposals. There are several areas where GEWEX can potentially contribute:

- GDAP: 1) improve integration of multi-agency, multi-national satellite-based products for closing the global water-carbon-energy budget and 2) integrate commercial satellite data for hydroclimate research
- GLASS/GASS: contribute to mission science and field campaign teams, e.g., using the GEWEX Land-Atmosphere Feedback Observatory (GLAFO) and other activities to support the Decadal survey incubator Missions on the, Planetary Boundary Layer (PBL) and Surface Topography and Vegetation (STV) observables
- GHP: Partner with NASA's Earth Action strategy, coordinate RHPs with airborne field campaigns, coordinate with the Global Learning and Observations to Benefit the Environment (GLOBE) program and Jet Propulsion Laboratory (JPL) Calibration & Validation (Cal/Val) program, for example, or NASA's Gravity Recovery And Climate Experiment (GRACE) groundwater estimates, and
- All GEWEX Panels could define a better role in the 7th Climate Model Intercomparison Project (CMIP7). Furthermore, GEWEX can facilitate and improve partnering and planning among the international space agencies on the Earth observing missions, advise on observational priorities and contribute to the Water and Energy Cycle Research Opportunity (contact Julie Vano at jvano@agci.org).

2 GEWEX Panel Status Reports

2.1 Global Atmospheric System Studies Panel (GASS)

Full Panel Name (Acronym) : Global Atmospheric System Studies (GASS)
Reporting Period : 01 January - 31 December 2024
Starting Date : ….
End Date (where appropriate) : N/A
URL : https://www.gewex.org/panels/global-atmospheric-system-studies-panel/

Membership

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

Members and Term Dates : Ann Fridlind 2021 – Present
Louise Nuijens 2024 – Present
Felix Pithan 2024 – Present
Martin Singh 2019 – Present
Pier Siebesma 2024 – 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

The GASS Panel is currently focused on addressing the following overarching questions through ongoing GASS projects:

- How do micro- to mesoscale atmospheric processes control global water and energy exchanges?
- What controls cloud phase and precipitation?
- What controls mesoscale organization?

List of 2 to 3 Key Results

- A special issue including 17 papers in *Climate Dynamics* was published by the LS4P project on "Sub-seasonal to Seasonal Predictability and Land-induced Forcing". Results indicated that both Tibetan Plateau and Rocky Mountains land surface temperature/subsurface temperature (LST/SUBT) had large control on the flood/drought in Southern China and Southern Great Plains, respectively.
- 10 LES models and 7 Single-Column Models (SCMs) have participated in the Cold-Air Outbreaks in the Marine Boundary Layer Experiment Model-Observation Intercomparison Project (COMBLE-MIP). Initial results included that 1) ice processes control mesoscale organization to first order in LES

results (comparing liquid-only and mixed-phase simulations) and 2) SCM models tend to deviate substantially from the LES models in diverse ways (e.g., far greater or lesser liquid and ice water path).

- Based on satellite and ML based data, results from the Upper Tropospheric Clouds and Convection Process Evaluation Study (UTCC PROES) indicated 1) large and more organized mature mesoscale convective systems (MCSs) seem to produce on average a larger radiative enhancement than smaller and less organized mature MCSs of similar rain intensity and 2) three convective regimes (bottom-heavy, mid-heavy and top-heavy) seem to be in a dynamic equilibrium with their relative occurrence nearly invariant during the whole life cycle (40–45%, 45%, 15–10%, respectively).

Other Science Highlights

- The DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains (DYAMOND) project submitted a proposal for DYAMOND-3 (third phase of DYAMOND), which will make the best use of the recent Organized Convection and EarthCARE Studies over the Tropical Atlantic (ORCESTRA) campaign and the new Earth Cloud Aerosol and Radiation Explorer (EarthCARE) satellite data.
- The DCP project has started to plan its phase II, focusing on simulation of the diurnal cycle of precipitation by high-resolution models with horizontal resolution from km scales to 25 km scale. Initial analysis of the US Department of Energy Exascale Earth System Model (E3SM) indicated that the model does not show better simulation of the diurnal cycle of precipitation at 25 km resolution compared to its low-resolution model with 100 km horizontal resolution due to the use of cumulus parameterization.
- The Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) project utilizes the nudging approach to evaluate Arctic boundary-layer and cloud processes in climate models with the data from the year-long central Arctic Ocean drift campaign MOSAiC. Their initial results indicated that CMIP6 models still tend to overestimate turbulent heat flux under stable stratification.

Panel Activities during Reporting Period

List of Panel Activities and Main Result

COMBLE-MIP

- 17 LES and SCM models joined COMBLE-MIP and submitted results
- Preliminary conclusions have been summarized in a concise number of figures for publication that span liquid-only and ice-containing model results
- Case setup and model descriptions collected in a manuscript that is expected to be shared with participants in early-to-mid 2025.

Cumulus Friction

- Three years of Atmospheric Model Intercomparison Project Phase 2 (AMIP-II) Aquaplanet simulations are analyzed for a CONTROL and CMTOFF experiment. Results will be summarized into papers.

DCP

- Published the overview paper on modeling the diurnal cycle of precipitation from global climate model (GCM) hindcasts and climate simulations
- Established initial communication with the contact persons for DYAMOND phase III and Hi-Res CMIP
- Performed initial analysis of the diurnal cycle of precipitation simulated by the 25 km resolution E3SM

DYAMOND

- Submitted a proposal for DYAMOND-3 (third phase of DYAMOND), which will make the best use of the recent ORCESTRA campaign and the new EarthCARE satellite data

GAP

- The GAP review has been published in *Nature Geosciences*.
- The GAP Radiative Convective Equilibrium (RCE) model intercomparison project (RCEMIP-ACI) aerosol perturbation experiment has been performed and is being analyzed.

LS4P

- LS4P side meeting held during the 2024 GEWEX Open Science Conference in Sapporo
- Working with several LS4P-II ESM groups to help them complete/conduct the LS4P-II experiments
- Organizing two LS4P regional climate modeling (RCM) group meetings (31 October 2024 and 6 January 2025) to discuss the LS4P-II RCM experiment progress and organize two RCM group papers for the LS4P-I RCM results
- Organized experiments and paper for catastrophic heavy rainfall events in Southern China and Bangladesh

MOSAiC

- Clarified variables and data structures and set up code for analyzing collected data
- Nudging the large-scale circulation in climate models allows the evaluation of model physics with data from short field campaigns
- Analyzed CMIP6 models still tend to overestimate turbulent heat flux under stable stratification

UTCC-PROES

- Analyzed the relation between latent and radiative heating in MCSs (results: Stephens et al., 2024; Masunaga and Takahashi, 2024; Chen et al., 2024).
- Evaluated MCSs in DYAMOND simulations (results: Prein et al., 2024; Feng et al., 2024).

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

COMBLE-MIP

- A second manuscript in preparation will focus on aerosol-aware simulations, will include full-domain LES results and will further analysis of mesoscale structure.

Cumulus Friction

- Test a number of hypotheses and write into a publication
- Possibly extend study to global weather models

DCP

- Performed initial analysis of the diurnal cycle of precipitation simulated by the 25 km resolution E3SM

GAP

- A paper describing the GAP Radiative Convective Equilibrium (RCE) model intercomparison project (RCEMIP-ACI) is getting in shape and will be submitted in the coming months

LS4P

- Plan to complete the LS4P-II experiment in 2025.

MOSAiC

- Analysis of submitted data is ongoing, progress in setting up code has mostly been achieved at the end of the year due to limited time resources. As a side result, the evaluation capabilities developed in the project contributed to evaluation of km-scale model runs at the Alfred Wegener Institute.

UTCC-PROES

- Characterizing deep convective organization using data (in cooperation with the Working Group on Deep Convective Organization) and link to anvil properties
- Synergy between Integrated Multisatellite Retrievals for GPM - Convection Tracking (IMERG-CT), Tracking Of Organized Convection Algorithm using a 3D segmentatioN (TOOCAN), Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) incarnation of the Cloud Properties continuity product (MODIS-CLDPROP) and Composite Infrared Spectrometer (CIRS)-ML

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

Establish collaborations between GASS and APARC. Potential areas include DYAMOND on deep convection, gravity waves, mesoscale circulations, orography and surface heterogeneities; UTCC PROES on clouds and circulation; LS4P on teleconnection processes on seasonal to subseasonal timescales; and ORCESTRA on the major recent field campaign observations.

COMBLE-MIP

- A possible activity that builds on COMBLE-MIP will be to compare COMBLE and Aerosol Cloud meTeorology Interactions oVer the Western ATlantic Experiment (ACTIVATE) conditions in a similar manner, with the objective of understanding phase feedback in climate models. This was discussed at the Paris CFMIP-GASS meeting in July 2023. NASA Goddard Institute for Space Studies (GISS) plans to commit 5–6 cases from each campaign to GitHub within the coming year (led by Florian Tornow).

DCP

- Phase 2 of the project is being planned, which will be focused on assessment of the diurnal cycle of precipitation by high-resolution models (km scales to ~25 km) through collaborating with DYAMOND phase III and HighResMIP II projects. The current leadership team will be changed.

DYAMOND

- Global storm-resolving MIPs are being planned

LS4P

- Plan to summarize the LS4P-II results and start LS4P-III in 2026

MOSAiC

- Analysis of nudged MOSAiC data, feedback to modeling groups and preparation of a manuscript in 2025 (Felix Pithan)
- Contribution to DYAMOND hackathon in May on moist intrusions (Felix Pithan)

UTCC-PROES

- Assessment of convective tracking datasets and of radiative heating rates (to be discussed during GDAP meeting)

Science Issues and Collaboration during Reporting Period

List of Contributions to Developing GEWEX Science and the GEWEX Imperatives

a. Data Sets

DCP

- Long-term observed large-scale forcing and evaluation data product over the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) and Amazon sites
- Global Precipitation Climatology Project (GPCP), Climate Prediction Center (CPC) MORPHing technique (CMORPH), and Global Precipitation Measurement (GPM) satellite precipitation data
- Model simulation data from 11 SCMs and 9 GCMs for more in-depth analysis that could be done by individual groups

MOSAiC

Nudged climate model output for the MOSAiC field campaign

UTCC PROES

- Introduction of a new data base of upper tropospheric cloud systems, based on cloud properties from infrared sounders (atmospheric infrared sounder, or AIRS, and the infrared atmospheric sounding interferometer, or IASI); this data base has been complemented by vertical structure, in particular radiative heating rates, and a precipitation rate classification, using machine learning and training with CloudSat-lidar nadir track observations. The addition of latent heating to this data base via machine learning makes the dataset complete for studying the role of upper tropospheric clouds in the feedback between atmospheric heating and circulation. The Clouds from Infrared Sounders (CIRS)-ML dataset, containing radiative heating rates and cloud properties from 30N–30S and from 2004–2018, is now released at: https://gewex-utcc-proes.aeris-data.fr/data/
- The TOOCAN database of mesoscale convective systems (MCSs) and their tracking, starting in 2012, was expanded to 2020
- There are now several other MCS tracking datasets available; some are not yet accessible to the public. First assessments are underway [for example, Prein et al., 2024; Feng et al., 2024; Atmosphere Observing System (AOS)-INvestigation of Convective UpdraftS (INCUS)-GEWEX Convection tracking algorithm and science workshop].

b. Analysis

DCP

Metrics and diagnostics used for evaluating the diurnal cycle of precipitation

LS4P

After reproducing the most of extreme warm May 2024 2-meter air temperature over the Tibetan Plateau, the CFSv2/SSiB generated about 55% of the observed extraordinary June 2024 rainfall anomaly in Southern China. The results passed the field significance test at $p<0.10$. The sea surface temperature (SST) effect produces 17% of observed rainfall anomaly. Within half year, research was completed and a paper was published in a high impact journal to identify the unknown cause of the catastrophic heavy rainfall and flooding in Southern China and Bangladesh, which demonstrated the robustness of LS4P. It normally takes at least 1–2 years to identify the cause (Li et al., 2025).

MOSAiC

Evaluation of climate models with respect to Arctic observations

UTCC PROES

- Upper tropospheric cloud system analysis to link anvil properties to convection, which can be applied to data, GCM and CRM simulations. This analysis now also includes vertical structure and radiative heating rates of cloud systems, as well as an estimation of latent heating rates.
- Tracking Analysis to determine life cycle of MCSs and to combine with heating

c. Processes

DCP

The group utilized the short-term hindcast approach with the ARM GoAmazon and Plains Elevated Convection at Night (PECAN) field campaign forcing and evaluation data for process studies on tropical and mid-latitude land convection.

LS4P

The group identified the mechanisms of how the Tibetan Plateau spring LST/SUBT anomaly affects the East Asian monsoon. Cold/warm May T2m and lower/higher sensible heat from the Tibetan Plateau surface in 2003/2024 case generated an anomalous meridional temperature gradient, shifting the westerly jet and producing upper-level vorticity and geopotential height anomalies through geostrophic relationship. The imposed LST/SUBT anomaly over the Tibetan Plateau provides eastward propagating wave energy for the upper-level vorticity and geopotential height anomalies to move southeastward, which in turn produces anomalies in moisture flux convergence and drought/flood in downstream region. Xue et al. (2024) discussed this process comprehensively. Li et al. (2025) produced a schematic diagram to describe this process.

MOSAiC

Improved understanding of Arctic boundary-layer processes and their interaction

UTCC PROES

Studied convection, convective organization, ice microphysics, radiative effects, detrainment.

d. Modeling

COMBLE-MIP

Expanding community case study analysis to the limit of supercooling (including homogeneous freezing) under cold-air outbreak conditions and pushing forward the use of prognostic droplet and ice prediction within the model intercomparison framework for LES and SCM.

DCP

Developed the prototypes for multi-model intercomparison studies.

LS4P

- The Korea Institute of Atmospheric Prediction Systems/ Korea Meteorological Administration group developed the land surface temperature initialization method to help reproduce the observed LST anomaly
- The Department of Energy Lawrence Livermore National Laboratory (LLNL) group introduced gravity wave drag to help improve the remote effect.

e. Application

LS4P

Applied the LS4P approach to investigate the cause and mechanisms of the summer 2024 catastrophic heavy rainfall in Southern China and Bangladesh.

UTCC PROES

Improved fundamental understanding and new process-oriented observational metrics will lead to an improvement of parameterizations in climate models, which then results in a reduced uncertainty of future climate projections.

f. Technology Transfer

…

g. Capacity Building

UTCC PROES

- different synergetic data analysis provides complementary information on processes.
- creating synergy between different scientific communities (working on satellite observations, radiative transfer and transport modeling, as well as small-scale process and climate modeling).

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?

LS4P

Identified the contribution of high mountain surface temperature on the prediction of local rainfall and its extreme under the climate change. In midlatitude, its effect is compariable to the SST effect, and problaly even larger in East Asia.

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?

COMBLE-MIP

Provided an observation-constrained test of the representation of high-latitude supercooled clouds, whose physics are likely important to predicted climate sensitivity measures.

UTCC PROES

In general, climate feedback studies are undertaken by climate model simulations, which rely upon their representation of convection and detrainment. Process-oriented evaluation of climate models will help to make them more reliable and thus to provide more certain climate feedback studies.

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)?

MOSAiC

The project aims to understand the Arctic boundary layer and the processes controlling it across seasons. In particular, it is interested in the wintertime temperature and moisture profiles and surface energy budget, and the springtime surface energy budget, here focusing on shortwave radiation.

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?

DCP

The short-range hindcasts indicated that the timing and amplitude of the diurnal cycle of precipitation is largely controlled by large-scale circulation over land.

LS4P

(1) A paper (Zhang et al., 2024), Near-global summer circulation response to the spring surface temperature anomaly in Tibetan Plateau — the GEWEX/LS4P first phase experiment, was published. The Tibetan Plateau-Rocky Mountains circumglobal wave train (TRC) modulated by the Tibetan Plateau thermal anomaly plays a critical role in the early summer surface air temperature and precipitation anomalies in the regions along the wave train, especially over the northwest North America and the southern Great Plains. The Tibetan Plateau LST/SUBT anomaly via the TRC wave train is the first order source of the subseasonal to seasonal variability in the hot spot regions. Furthermore, the TP surface temperature anomaly can influence the Southern Hemispheric circulation by generating cross-equator wave trains. However, the simulated propagation pathways from the Tibetan Plateau into the Southern Hemisphere show large inter-model differences. (2) A schematic diagram in Li et al. (2025) illustrates the remote control of the Tibetan Plateau LST anomaly on continental scale circulation.

MOSAiC

The project effectively fixed the large-scale circulation in its setup, and study features that are mostly constrained by the large-scale circulation.

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?

DCP

The coupling between convection and surface is overly strong in most of the GCMs, which has resulted in the problem that most GCMs present a noon precipitation peak rather than the late afternoon perk shown in the observation over land.

LS4P

Identify the remote interaction of high mountain land surface temperature and downstream regions' precipitation prediction.

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?

…

Other Key Science Questions

COMBLE-MIP
It is anticipated that the sensitivity of precipitation efficiency to supercooling will be a subject of growing interest for the quantification of cloud phase feedback.

LS4P

How does the LST/SUBT over the Andes influence the SST and southern hemisphere circulation and precipitation?

Contributions to WCRP including the WCRP Light House Activities

COMBLE-MIP has relevance for predicting Earth system change as it relates to Arctic amplification and the transition of some supercooled clouds to a warm state with climate change.

UTCC PROES

The expansion of cloud vertical structure, radiative and latent heating via Machine Learning and linking to cloud systems and their environment to get a more complete observational picture of our planet should be very relevant to Digital Earth.

Cooperation with other WCRP projects, outside bodies and links to applications

COMBLE-MIP
Collaboration with the International Cloud Modeling Workshop (ICMW) on COMBLE-MIP was discussed in South Korea in July 2024. The ICMW leadership team expressed interest in increased collaborative activities. This issue was brought to a subsequent GASS Panel meeting by Fridlind, where Panel members welcomed future engagement with ICMW, which was shared back to Lulin Xue and ICMW. No concrete plans at this time, but lines of communication are open.

UTCC PROES may reach out to the Gravity Waves activity group of APARC.

Workshops and Meetings

List of Workshops and Meetings Held in 2024

- The LS4P side meeting on 11th July 2024 during the 2024 GEWEX Open Science Conference in Sapporo
- Conduct several LS4P-II ESM groups to help them complete/conduct the LS4P-II experiments
- Two LS4P RCM group meetings (31 October 2024 and 6 January 2025) through Zoom
- AOS-INCUS-GEWEX Convection tracking algorithm and science workshop from 23–25 April 2024, GISS, New York, USA (*https://sites.google.com/view/convection-tracking-workshop/home*)

List of Workshops and Meetings Planned in 2025 and 2026

- Pan-GASS meeting anticipated in 2026
- COMBLE-MIP: Cooperation is being conducted via virtual meeting tools on an as-needed basis
- UTCC-PROES – GDAP meeting: 19–21 May and 21–25 May 2025, Sorbonne University, Paris, France
- The 2025 CFMIP Meeting from 7–10 July 2025, in Exeter, UK

Other Meetings Attended on Behalf of GEWEX or Panel in 2024

- Juliano represented the COMBLE-MIP work at the 11th International Cloud Modeling Workshop in Seoul, South Korea from 8-12 July 2024
- GEO-RING workshop, 29 Feb – 1 Mar 2024, EUMETSAT, Darmstadt, Germany. Invited talks: 1) "GEWEX Perspective for ISCCP-NG" (C. Stubenrauch). 2) Use of Geo-ring radiances, and requirements for a tracking purpose of deep convective systems (T. Fiolleau)

Publications during Reporting Period

List of Key Publications

Ardilouze, C., Boone, A.A. Impact of initializing the soil with a thermally and hydrologically balanced state on subseasonal predictability. Clim Dyn 62, 2629–2644 (2024). https://doi.org/10.1007/s00382-023-07024-x

Chen, X., C.J. Stubenrauch, G. Mandorli, Relationship between latent and radiative heating fields of Tropical cloud systems using synergistic satellite observations, EGUsphere [preprint] (2024) doi:10.5194/egusphere-2024-3434 (in review)

Derras-Chouk, A., and Z.J. Luo, A geostationary satellite-based approach to estimate convective mass flux and revisit the hot tower hypothesis. Surv. Geophys., 45, 1959-1977(2024) doi:10.1007/s10712-024-09856-6

Feng, Z., A. Prein, J. Kukulies, T. Fiolleau, W. K. Jones, B. Maybee, Z.L. Moon, K.M. Núñez Ocasio, W. Dong, M.J. Molina, M.G. Albright, R. Feng, J. Song, F. Song, L.R. Leung, A.C. Varble, C. Klein, R. Roca, Mesoscale Convective Systems tracking Method Intercomparison (MCSMIP): Application to DYAMOND Global km-scale Simulations, ESS Open Archive [preprint] (2024) doi:10.22541/essoar.172405876.67413040/v1

Gasparini, B., G. Mandorli, C. J. Stubenrauch, A. Voigt, Basic Physics Predicts Stronger High Cloud Radiative Heating With Warming, Geophys. Res. Lett., 51, e2024GL111228, (2024) doi:10.1029/2024GL111228

Guy Dagan, Susan C. van den Heever, Philip Stier, Tristan H. Abbott, Christian Barthlott5, Jean-Pierre Chaboureau, Jiwen Fan, Stephan de Roode, Blaˇz Gasparini, Corinna Hoose, Fredrik Jansson, Gayatri Kulkarni, Gabrielle Leung, Thara Prabhakaran, David M. Romps,

Denis Shum, Mirjam Tijhuis , Chiel C. van Heerwaarden, Allison Wing, Yunpeng Shan, RCEMIP-ACI: Aerosol-Cloud Interactions in a Multimodel Ensemble of Radiative-Convective Equilibrium Simulations, Journal of Advances in Modeling Earth Systems (JAMES), in preparation.

Li, Q., Y. Xue, X. Konga, W. K-M Lau, A. Wang, Q.P. Li, Z. Cao, H. Nayak, G. Xu, W. Guo, Ratko V., 2025: Excessive Tibetan Plateau Spring Warming Found to Cause Catastrophic June 2024 Heavy Rainfall in China. Science Bulletin, https://doi.org/10.1016/j.scib.2025.01.01.

Mandorli, G., C.J. Stubenrauch, Assessment of object-based indices to identify convective organization, Geosci. Model Dev., 17, 7795–7813 (2024) doi:10.5194/gmd-17-7795-2024

Masunaga, H., H. Takahashi, The Energetics of the Lagrangian Evolution of Tropical Convective Systems, J. Atmos. Sci., 81, 783-799 (2024) doi:10.1175/JAS-D-23-0141.1

McKim, B., S. Bony, J.-L. Dufresne, Weak anvil cloud area feedback suggested by physical and observational constraints, Nat. Geoscience, 17, 392-397 (2024) doi:10.1038/s41561-024-01414-4

Prein, A., Feng, Z., Fiolleau, T., Moon, Z., Nunez Ocasio, K., Kukulies, J., Roca, R., Varble, A., Rehbein, A., Liu, C., Ikeda, K., Mu, Y. and Rasmussen, R., Km-Scale Simulations of Mesoscale Convective Systems Over South America - A Feature Tracker Intercomparison, J. Geophys. Res., 129, e2023JD040254 (2024) doi:10.1029/2023JD040254

Rossow, W., B., Evolution of the concept of cloud-climate feedbacks, J. Europ. Meteor. Soc., 1, 100004 (2024) doi:10.1016/j.jemets.2024.100004

Stephens, G.L., K.A. Shiro, M.Z. Hakuba, H. Takahashi, J.A. Pilewskie, T. Andrews, C.J. Stubenrauch, and L. Wu, Tropical deep convection, cloud feedbacks and climate sensitivity. Surv. Geophys., 45, 1903-1931 (2024) doi:10.1007/s10712-024-09831-1

Tao, C., Xie, S., Ma, H.-Y., Bechtold, P., Cui, Z., Vaillancourt, P.A., et al. (2024) Diurnal cycle of precipitation over the tropics and central United States: intercomparison of general circulation models. Quarterly Journal of the Royal Meteorological Society, 1–26. Available from: https://doi.org/10.1002/qj.4629.

Takahashi, H., Z.J. Luo, H. Masunaga, R. Storer, A.T. Noda, Investigating Convective Processes Underlying ENSO: NewInsights Into the Fixed Anvil Temperature Hypothesis, Geophys. Res. Lett., 51, e2023GL107113 (2024) doi:10.1029/2023GL107113

Takasuka, D., Satoh, M., Miyakawa, T. et al. A protocol and analysis of year-long simulations of global storm-resolving models and beyond. Prog Earth Planet Sci 11, 66 (2024). https://doi.org/10.1186/s40645-024-00668-1.

Stier, P., S. C. van den Heever, M. W. Christensen, E. Gryspeerdt, G. Dagan, S. M. Saleeby, M. Bollasina, L. Donner, K. Emanuel, A. M. L. Ekman, G. Feingold, P. Field, P. Forster, J. Haywood, R. Kahn, I. Koren, C. Kummerow, T. L'Ecuyer, U. Lohmann, Y. Ming, G. Myhre, J. Quaas, D. Rosenfeld, B. Samset, A. Seifert, G. Stephens, and W. K. Tao (2024), Multifaceted aerosol effects on precipitation, Nat Geosci, 17(8), 719-732, doi:10.1038/s41561-024-01482-6.

Voigt, A., North, S., Gasparini, B., and Ham, S.-H., Atmospheric cloud-radiative heating in CMIP6 and observations and its response to surface warming, Atmos. Chem. Phys., 24, 9749–9775 (2024) doi:10.5194/acp-24-9749-2024

Xue, Y. and W. K-M Lau, 2024: Preface: Subseasonal-to-seasonal predictability of extreme precipitation and land forcing. Climate Dynamics. 62, 2599-2600, DOI. 10.1007/s00382-024-07203-4

Zhang, Y., Y. Pan, Y. Xue, I. Diallo, X. Zeng, S. Li, J. D Neelin, W. K.M. Lau, A. A. Boone, F Vitart., T. Yao, Q. Tang, T. Sato, M.-S. Koo, C. Ardilouze, S. K. Saha, J. Yang, S. Materia, Z. Lin, X. Qi, Y. Qin, T. Nakamura, P. Nobre, D. Peano, R. Senan, Y. Takaya, H. Wang, H. Zhang, Y. Zhan, M. Zhao , C. R. Mechoso, Q. Bao , M. J. Bottino, S. Hong, Y. Lin, S. Xie, X. Pan, H. P. Nayak, S. C. Chou, W. Guo, 2024: Near-global summer circulation response to the spring surface Temperature anomaly in Tibetan Plateau ---- The GEWEX/LS4P First Phase Experiment. Climate Dynamics. 62, 2907-2924, DOI: 10.1007/s00382-024-07210-5

NOTE:

COMBLE-MIP: All progress currently documented at https://arm-development.github.io/comble-mip and first manuscript is now in preparation, with all figures nearly finalized and most text prepared, including model descriptions and references.

LS4P published a special issue, "Climate Dynamics Special Issue "Sub-seasonal to Seasonal (S2S) predictability and Land-induced Forcing," in Climate Dynamics in April 2024. Seventeen papers were included in the issue. The PI and Dr. William Lau wrote the preface to briefly review the current stages of research in this field. Furthermore, with the help of the Climate Dynamics editorial Office, a topical collection entitled "Land surface impacts on precipitation predictability over Subseasonal-to-Seasonal (S2S) and longer time scales" has also been established (https://link.springer.com/collections/ddggehccjd). Nineteen papers have been included in this collection.

2.1.1 GASS Rapporteurs Report

Panel: Global Atmospheric System Studies (GASS) Panel
Rapporteur(s): Myoung-Hwan Ahn, Ruby Leung and Gavin Schmidt

Adherence to GEWEX and Panel's objective(s)

Through various activities to promote and facilitate the coordination of projects involving the development and use of observations, process studies and a hierarchy of numerical models, GASS panel activities have adhered very well to the panel's objective "to improve the understanding of physical processes in the atmosphere, and their coupling to the surface and atmospheric dynamics, with the goal of advancing the understanding and prediction of weather and climate.

Achievement of annual goals for this reporting period

The GASS panel has set annual goals to address questions on the processes that control cloud phase and precipitation, mesocale organization as well as understanding how the smaller scales control global water and energy exchange which are achieved through coordination of 10 ongoing GASS projects focusing on improving understanding and modeling of various atmospheric processes including diurnal cycle of precipitation, aerosol-precipitation interactions, tropospheric clouds and convection, shallow cumulus friction, mesoscale organization of deep and shallow convection, convective clouds during Arctic cold-air outbreaks, land's influence and teleconnection, Arctic climate processes, and global storm-resolving modeling.

Major accomplishments and results in reporting period

Major accomplishments are provided in detail in the GASS panel report. These include innovative use of new observations from field campaigns (e.g., ORCESTRA, COMBLE, EUREC4A) and satellite data, improving use of large-eddy simulations and cloud-resolving modeling over increasingly large domains in idealized or realistic configurations (e.g., DYAMOND, Digital Earth LHA), impactful land initialization experiments revealing S2S predictability, and publications from the various projects. The GASS panel has also pursued synergies and complementarities with other WCRP activities (e.g., Digital Earth LHA, CFMIP, GPEX) and WGNE activities.

Overall, the GASS co-chairs and panel members are to be commended on their excellent efforts in leading and coordinating 10 community projects addressing important gaps in understanding and modeling atmosphere/climate processes.

Arisen or noted science issues

While significant accomplishments have been made through the various projects, the number of projects is relatively large. The panel could consider consolidating some projects for larger impacts and streamlining the coordination effort.

Emerging Science

With AI/ML rapidly incorporated in atmospheric and Earth sciences to advance modeling, prediction, and model-data integration, the GASS panel may consider leveraging AI/ML toward achieving its science goals or contribute to facilitating/coordinating community activities in this space to add value.

Future plans

The GASS panel is considering future opportunities related to the use of new observations (including exploiting past and future field campaigns and satellite data), increasing the use of LES and cloud-resolving models and new, emerging generation of climate models, and leveraging new technologies including AI/ML to explore model sensitivity to parameter choices, gaining a deeper understanding of physical processes, and bridging between observations and modeling.

Recommendations to Panel

Here are some specific recommendations from the SSG to the GASS panel:

- It's exciting to see new campaign data being used, but GASS may also consider leveraging data from previous field campaigns to understand processes and evaluate models in more diverse regions, particularly regions in the tropics and southern hemisphere where the lack of data is often a limiting factor.
- It's good to see the GASS connection to the WCRP Digital Earth LHA through the DYAMOND contribution to the km-scale modeling hackathon to facilitate broader participation by the community in utilizing km-scale models and simulations in their research.
- It's good to see the Deep Organization project's plan to build on the km-scale hackathon to jump-start some activities. This project may also incorporate MCS-focused activities inside and outside of GASS in its model intercomparison plan.
- LS4P has made significant progress in advancing the methodology of initializing land temperature and snowpack and understanding the impact on S2S prediction. Is this a good time to encourage more participation by operational modeling centers and groups that run operational models to stress test the impact on operational S2S forecasts?
- GAP has a goal to "facilitate connections between all GEWEX and related process-based activities on Aerosol-Cloud-Precipitation (ACP) interactions". Noticeably few activities within GEWEX have an ACP component, despite the importance of aerosols in both the energy and water cycles. Can GAP articulate the need for crosscutting ACP activities that may promote interests in other panels? Will GAP leverage datasets such as PACE that will be released shortly?
- One missing element of DYAMOND might be how these runs could be used to inform coarser resolution model parameterizations. Perhaps this challenge can be addressed in collaboration with the Digital Earth LHA or other GASS projects (e.g., DCP)?
- Organized deep convection is a key aspect of several projects – DYAMOND, Deep Organization, UTCC-PROES, Digital Earth, GPEX, etc. What roles can GASS play in coordinating and contributing to various activities for larger impacts?
- Is there an opportunity for project collaboration on shallow and deep convection towards improving understanding and modeling of their connections?

Considerations for SSG

GASS may consider consolidating the 10 projects, where it makes sense, and extend engagement with other panels and WCRP activities.
GASS may also consider developing a coordinated activity with other panels this year, with the goal of adding this activity as a project in 2027.

Additional Remarks

The SSG suggests future GASS panel reports should include activities conducted or actions taken in response to the comments from the SSG rapporteurs.

2.2 GEWEX Data and Analysis Panel (GDAP)

Full Panel Name (Acronym) : GEWEX Data and Analysis Panel (GDAP)
Reporting Period : 01 January - 31 December 2024
Starting Date : ….
End Date (where appropriate) : N/A
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
Benoit Meyssignac, 2022 – Present
Brent Roberts, 2023 – Present
Hanii Takahashi, 2024 – Present
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 references networks. Trigger new international initiatives to support GEWEX science objectives and inform the research community at large.

List of Panel Goals

- 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, GPCP, 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/EEI assessments, GVAP)
- Support ground-based networks (e.g. BSRN, GPCC)
- Act as an interface between satellite datasets and GEWEX activities such as the PROES, GAP, and other GEWEX panels (GLASS, GASS, and GHP)
- Maintain links to other data-oriented working groups and panels (e.g. CGMS, IPWG)
- 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

- Added a new panel member (Hanii Takahashi) to maintain Panel's demographic and topical diversities.
- In 2024, the EEI assessment team published a comprehensive inter-comparison of the TOA radiation budget, ocean heat content rate estimates from ocean in-situ temperatures and from space geodesy (altimetry and space gravimetry) (see Hakuba et al. 2024). This assessment shows that among 21 OHC datasets that were analyzed, the ocean heat uptake (OHU) estimates range from 0.40 ± 0.12 to 0.96 ± 0.08 W/m² (2005–2019). The discrepancies in OHU arise from different quality control of the data and mapping methods (the correction for unequal ocean sampling slightly reduces the spread of estimates).
- The ISCCP-NG team published in ACP on key results from G-VAP Phase II (Trent et al., 2024, https://doi.org/10.5194/acp-24-9667-2024)
- The BSRN team published a best practices paper for ocean radiometric measurements in collaboration with OASIS and others in the ocean measurement community: Riihimaki, L. D., Cronin, M. F., et al. (2024). Ocean surface radiation measurement best practices. Frontiers in Marine Science, 11, 1359149, https://doi.org/10.3389/fmars.2024.1359149

Other Science Highlights

- EEI products with better observational coverage (e.g., satellites) or that account for sparse regions (reanalysis or hybrid products using in-situ and satellite data) track EEI variability more accurately showing a better correlation with the TOA radiation budget record than in situ-only datasets. Satellites and hybrid products all show a trend in OHU ranging between 0.32 ± 0.25 to 0.52 ± 0.10 W/m² per decade (2005–2019)
- ISCCP-NG prototype data used in the TOOCAN cloud tracking algorithm
- 369 new files have been incorporated int the BSRN archive in 2024. 190 of them are related to 2024 and provided by 21 out of 43 active stations.

Panel Activities during Reporting Period

List of Panel Activities and Main Result

EEI

- Gathered the OHC datasets produced across the community from in-situ temperature, from satellite altimetry and gravimetry and from reAnalysis. Analyzed the datasets and published a first intercomparison of the different products within the same community and across communities (i.e. between the in-situ community, the geodetic community and the radiometry community)
- Participated in the International Space Science Institute workshop on the Earth's changing water energy cycle and to the Survey of Geophysics special edition on the Earth's changing water energy cycle
- Prepared a 2025 workshop to discuss with the whole community the results of the first published intercomparison and to entrain a larger community
- The EEI assessment paper is published in the special issue of Survey in Geophysics on the Earth's changing water and energy cycle: https://link.springer.com/collections/jjaigeegcg
- The EEI assessment paper identified a group of OHU estimates based on satellite and in-situ data which agree in terms of interannual variability and trend with the TOA radiation budget record from CERES. It also pinpointed systematic differences in the processes used to derive OHU estimates from in-situ data and from satellite data that are responsible for the large uncertainty range of in-situ only OHU estimates

- The next EEI workshop will be held in US in 2025 and should enable to entrain a larger community in particular in US.
- Intercomparisons of various water vapor data records: distinct regional differences are observed over the poles (relative values) and parts of the tropical land.
- Analysis of stability/homogeneity and estimation of trends and the response to SST, LST, and T2m: most data records are affected by (partly small) breakpoints. Trends and regression results exhibit differences among the records and relative to expectations, though a subset of records shows agreement despite small breakpoints.

GVAP-II

Characterization of the clear-sky bias: methods have been developed to estimate the clear-sky bias by using reanalysis and GNSS data. Though the uncertainty of the bias estimates is larger than the actual bias, the bias estimates from the two different data bases are in good agreement.

ISCCP-NG

ISCCP-NG: Held a 2nd ISCCP-NG Workshop at EUMETSAT in Darmstadt that followed the CGMS International Cloud Working Group (ICWG).
ISCCP-NG: 2nd Workshop was focused on the applications of ISCCP-NG and included talks from the aerosol, precipitation, cloud tracking and cloud product communities.

BSRN

BSRN data is available via our website: https://bsrn.awi.de/data/data-retrieval-via-pangaea/

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

EEI

The panel is currently organizing a new EEI assessment workshop to take place in spring 2025. In 2025 the panel will bring together all the gridded datasets relevant to the estimate of the EEI and propose a common, unified ensemble which gathers these datasets in the form of grids (instead of time series) in a common format to ease the analysis and the use of the OHC products.
The EEI assessment panel will also participate to the WCRP EPESC lighthouse activity on analyzing the current trend in EEI.

ISCCP-NG

ICWG is planning a cloud product comparison using the current ISCCP-NG L1g demo. This will help this community determine the requirements for cloudiness information from ISCCP-NG.

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

General

Cloud tracking assessment, led by Hanii Takahashi, is an emerging activity that will be a promising addition to the GDAP portfolio. Convective tracking dovetails with the ISCCP-NG activity as a potential science application of the L1G product. It will also feature in future directions with the UTCC PROES project, led within the GASS Panel.

EEI

In the coming 2 years the panel should start to write the first version of the synthetic report on the GEWEX EEI assessment activity.

ISCCP-NG

EUMETSAT is planning on generating a 5-year ISCCP-NG L1g data set and will host with NOAA in a cloud service.

Science Issues and Collaboration during Reporting Period

Contributions to Developing GEWEX Science and the GEWEX Imperatives.

a. Data Sets

EEI

- In 2023-2024 the EEI assessment panel gathered global OHC products (time series) and made this dataset freely available on a website to enable the analysis of the EEI by the community.
- In 2025-2026 the EEI assessment panel will gather regional grids of OHC products and make these datasets freely available on a website to enable the analysis of the EEI to the community.

GVAP-II

G-VAP results exhibit strengths and weaknesses of the available water vapor data records. The documented/published information is considered valuable in triggering improvements by the data record PIs. Access to an archive of data supports joined analysis and additional lessons learned from outside G-VAP. At present, the archive from Phase 1 is online only.

ISCCP-NG

ISCCP-NG L1g data will grow to span 5-years once processed by EUMETSAT.

b. Analysis

EEI

In 2024 the EEI assessment panel made an analysis of the EEI estimates from OHC products and assessed their consistency. They analyzed and explained the discrepancies. They evaluate the uncertainty estimates and the causes for their spread. They also compared these OHC estimates with the TOA radiation budget estimate from CERES. From this analysis came out a set of recommendations to improve EEI estimates form in-situ and geodetic approaches and proposed way forward to better characterize uncertainties and make them more consistent across approaches. The analysis also examined the impact of data gaps in the EEI record in terms of EEI trend estimates.

GVAP-II

A strong focus in G-VAP is on analyzing climate variability and change (though with the objective to identify issues in the data). Results related to trend and regression estimation were mentioned above. An analysis of correlation to climate indices reveals a generally good agreement among the analyzed data records.

c. Processes

…

d. Modeling

…

e. Application

GVAP-II

Instead of focusing on attribution, 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.

ISCCP-NG

We continue to discuss the application of precipitation, cloud tracking and aerosol studies to ISCCP-NG L1g.

f. Technology Transfer

ISCCP-NG

ISCCP-NG L1g code has been shared with EUMETSAT and is being co-developed at multiple space agencies.

g. Capacity Building

GVAP-II

In-house (NMHS) exchange with climate modelers on using data archives for model evaluation.

BSRN

Ocean Radiometer best Practices paper published

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?

GVAP-II

Changes in TCWV were analyzed using the G-VAP data archive v2. To a large extend, 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 over land.

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?

EEI

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

3. Precipitation Extremes:

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

…

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?

EEI

The Earth energy imbalance assessment outputs are used to constrain estimates of the global climate feedback parameter variations over the past decades in e.g. the EPESC lighthouse activity, or in the ESA

MOTECUSOMA project. The reduced uncertainty in EEI enables to show that the global climate feedback parameter has changed with the pacific decadal oscillation over the past decades. The Earth energy imbalance assessment outputs have been also used to constrain the equilibrium climate sensitivity (Otto et al. 2014, Curry et al. 2018, Chenal et al. 2022). Reduced uncertainty in EEI improves the estimate of the lower range of the equilibrium climate sensitivity.

GVAP-II

G-VAP assesses the impact of increasing temperature on atmospheric water vapor but hardly improves our understanding of underlying mechanisms.

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)?

GVAP-II

Efforts on analyzing water vapour in the ABL but not (yet) in light of the above 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?

…

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?

…

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

…

Contributions to WCRP including the WCRP Light House Activities

EEI

The EEI assessment panel participate to the EPESC lighthouse activity on analyzing and explaining the current trend in EEI. They support actively the EPESC WG1 in this objective.

GVAP-II

Analysis of homogeneity, trends and regression (Explaining and Predicting Earth System Change)

Cooperation with other WCRP Projects, Outside Bodies and Links to Applications

EEI

The EEI assessment panel also participates to the GCOS-WCRP initiative on Earth energy, water and carbon budgets (https://www.wcrp-climate.org/news/wcrp-news/2080-wcrp-cgos-report-11-23)

GVAP-II

In contact with SPARC through the ESA WV_cci project.

BSRN

While BSRN doesn't directly work on scientific research, many members of the BSRN community and users of BSRN data work on research related to GEWEX science goals. In particular, the surface radiative energy budget is critical for quantifying the surface energy budget and the exchange of energy and water between the surface and the atmosphere as well as understanding boundary layer processes and land-atmosphere interactions.

Workshops and Meetings

List of Workshops and Meetings Held in 2024

General

2024 GDAP meeting, Sapporo, 6 July, in conjunction with the 9th GEWEX Open Science Conference (OSC)
GEWEX cross-panel meeting, 9 July, as an evening breakout session of the 9th GEWEX OSC

EEI

About 15 panel meetings held in visio in the course of the year to organize the EEI assessment activity.

BSRN

18th BSRN Scientific Review and Workshop, Tokyo, July 1-5, Hosted by JMA and supported by GEWEX

List of Workshops and Meetings Planned in 2025 and 2026

General

2025 GDAP meeting in Paris, 22-23 May 2025, in conjunction with a UTCC PROES meeting (19-21 May)

EEI

About 15 panel meetings will be hold in visio in the course of the year to organize the EEI assessment activity
We expect to hold the 2nd EEI assessment workshop in US in spring 2025**.**

GVAP-II

The GEWEX Water Vapor Assessment Workshop, current planning: Copenhagen, Denmark, September 2025

BSRN

19th BSRN Scientific Review and Workshop, location/date TBD, planned for 2026 – support will be needed for station scientists to attend who cannot afford to do so otherwise.

Other Meetings Attended On Behalf of GEWEX or Panel in 2024

EEI

- T. Boyer, B. Meyssignac, M. Z. Hakuba, S. Kato, Ocean Heat Content: Global Energy and Water Exchange (GEWEX) Global Data Assessment Panel (GDAP) assessment of Earth's Energy Imbalance, Joint International Quality Controlled Oceanographic Database, Global Temperature and Salinity Profile Program, Ship of Opportunity Panel and Expendable Bathythermograph Science meeting, Nov. 14, 2024, Bologna, Italy
- E. Leuliette, D. A. Byrne, M. Z. Hakuba, T. Boyer, L. Cheng, S. Fourest, P. Lavin, R. Locarnini, B. Meyssignac, A. Mishonov, J. Reagan, H. Roman-Stork, Z. Wang, "Global Ocean Heat Content": Satellite and in situ methods compared and combined" 30 Years of Progress in Radar Altimetry Symposium, September 4, 2024, Montpelier, France
- B.Meyssignac, N.Loeb, M.Hakuba, T.Boyer, S.Kato "Mean, trend, variability and uncertainty in Earth's Energy Imbalance over the last two decades" European Geophysical Union, Avril 2024, Vienne.
- B.Meyssignac , N.Loeb, T.Andrews, S.Bauer, K.Findell, P.Heimbach, G.Johnson, R.Kramer , M.Mayer, S.P.Raghuraman, P.Kushner, S.Winkelbauer "Evidence of a Trend in Earth's Energy Imbalance: Investigating Possible Causes and Implications", WCRP ESPESC meeting 16-17 Mai, Barcelone.
- T. Boyer, Benoit Meyssignac, S. Kato, M. Z.Hakuba, J. Benveniste, J. Reagan, "The Global Energy and Water Exchanges (GEWEX) Earth's Energy Imbalance Assessment", Ocean Sciences, Feb 22, 2024, New Orleans, USA
- T. Boyer, B. Meyssignac, S. Kato, M. Z. Hakuba and J. Benveniste "Global Energy and Water Cycle (GEWEX) Earth's Energy Imbalance Uncertainty Quantification", American Geophysical Union Fall meeting, December 8, 2024, San Francisco, USA
- Benoit Meyssignac, M.Hakuba, T.Boyer and S.Kato "Mean, trend, variability and uncertainty in Earth's Energy Imbalance over the last two decades", WCRP Open Science Conference, 23 Oct 2023, Kigali, Rwanda.

GVAP-II

- GEWEX Open Science Conference, Sapporo, Japan, July 2024

BSRN

- NDAAC Annual Steering Committee Meeting 11-15 November 2024--Amelie reported remotely on BSRN progress
- 29th Session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC), Asheville, NC, 17-20 September 2024 – Laura attended in person and reported on BSRN progress
- International Radiation Commission business meeting June 2024 Hangzhou, China -- Christian Lanconelli attended remotely to report BSRN
- 2024 GDAP panel meeting in Sapporo – Laura attended to give an update on BSRN

Publications during Reporting Period

List of Key Publications

EEI

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

Cheng, L., Foster, G., Hausfather, Z., Trenberth, K. E., & Abraham, J. (2022). Improved quantification of the rate of ocean warming, Journal of Climate, 35, 14, 4827–4840, https://doi.org/10.1175/JCLI-D-21-0895.1

Cheng, L. Sensitivity of Ocean Heat Content to Various Instrumental Platforms in Global Ocean Observing Systems. Ocean-Land-Atmos Res. 2024;3:0037. DOI:10.34133/olar.0037

Giglio, D., Sukianto, T., & Kuusela, M. (2023). Ocean Heat Content Anomalies in the North Atlantic based on mapping Argo data using local Gaussian processes defined over space (1.0.0) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.10183869

Hakuba, M.Z., Fourest, S., Boyer, T. et al. (2024) Trends and Variability in Earth's Energy Imbalance and Ocean Heat Uptake Since 2005. Surv Geophys. https://doi.org/10.1007/s10712-024-09849-5

Hakuba, M. Z., Frederikse, T., and Landerer, F. W.: Earth's Energy Imbalance From the Ocean Perspective (2005–2019), Geophys. Res. Lett., 48, e2021GL093624, https://doi.org/10.1029/2021GL093624, 2021

Johnson, G.C., Landerer, F.W., Loeb, N.G. et al. Closure of Earth's Global Seasonal Cycle of Energy Storage. Surv Geophys (2023). https://doi.org/10.1007/s10712-023-09797-6

Li, X., Li, Q., Wild, M. et al. An intensification of surface Earth's energy imbalance since the late 20th century. Commun Earth Environ 5, 644 (2024). https://doi-org.insu.bib.cnrs.fr/10.1038/s43247-024-01802-z

Loeb, N.G., Ham, SH., Allan, R.P. et al. (2024) Observational Assessment of Changes in Earth's Energy Imbalance Since 2000. Surv Geophys. https://doi.org/10.1007/s10712-024-09838-8

Loeb, N. G., Johnson, G. C., Thorsen, T. J., Lyman, J. M., Rose, F. G., & Kato, S. (2021). Satellite and ocean data reveal marked increase in Earth's heating rate. Geophysical Research Letters, 48, e2021GL093047. https://doi-org.insu.bib.cnrs.fr/10.1029/2021GL093047

Loeb, N., Lyman, J., Johnson, G. et al. Observed changes in top-of-the-atmosphere radiation and upper-ocean heating consistent within uncertainty. Nature Geosci 5, 110–113 (2012). https://doi.org/10.1038/ngeo1375

Lyman, J. M., and G. C. Johnson, 2023: Global High-Resolution Random Forest Regression Maps of Ocean Heat Content Anomalies Using In Situ and Satellite Data. J. Atmos. Oceanic Technol., 40, 575–586, https://doi.org/10.1175/JTECH-D-22-0058.1

Marti, F., Meyssignac, B., Rousseau, V., Ablain, M., Fraudeau, R., Blazquez, A., and Fourest, S.: Monitoring global ocean heat content from space geodetic observations to estimate the Earth energy imbalance (2024) in: 8th edition of the Copernicus Ocean State Report (OSR8), edited by: von Schuckmann, K., Moreira, L., Grégoire, M., Marcos, M., Staneva, J.,

Brasseur, P., Garric, G., Lionello, P., Karstensen, J., and Neukermans, G., Copernicus Publications, State Planet, 4-osr8, 3, https://doi.org/10.5194/sp-4-osr8-3-2024

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.: 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://essd.copernicus.org/articles/14/229/2022/ , 2022.

Meyssignac, B., Fourest, S., Mayer, M. et al. (2024) North Atlantic Heat Transport Convergence Derived from a Regional Energy Budget Using Different Ocean Heat Content Estimates. Surv Geophys. https://doi.org/10.1007/s10712-024-09865-5

Meyssignac, B., Boyer, T., Zhao, Z., Hakuba, M. Z., Landerer, F. W., Stammer, D., Köhl, A., Kato, S., L'Ecuyer, T., Ablain, M., Abraham, J. P., Blazquez, A., Cazenave, A., Church, J. A., Cowley, R., Cheng, L., Domingues, C. M., Giglio, D., Gouretski, V., Ishii, M., Johnson, G. C., Killick, R. E., Legler, D., Llovel, W., Lyman, J., Palmer, M. D., Piotrowicz, S., Purkey, S. G., Roemmich, D., Roca, R., Savita, A., von Schuckmann, K., Speich, S., Stephens, G., Wang, G., Wijffels, S. E., and Zilberman, N.: Measuring Global Ocean Heat Content to Estimate the Earth Energy Imbalance, Front. Mar. Sci., 6, 432, https://doi.org/10.3389/fmars.2019.00432, 2019.

Meyssignac, B., Chenal, J., Loeb, N., Guillaume-Castel R. and Ribes A. (2023b) Time-variations of the climate feedback parameter λ are associated with the Pacific Decadal Oscillation. Commun Earth Environ 4, 241 (2023). https://doi-org.insu.bib.cnrs.fr/10.1038/s43247-023-00887-2

Meyssignac, B., Hakuba, M.Z., Kato, S., Boyer, T., and Benveniste, J. (2023). First Earth Energy Imbalance Assessment WCRP-ESA Workshop Summary and Recommendations Executive Brief, ESA Publication, http://doi.org/10.5270/wcrp-esa-eeia- 2023 final_report_brief

Minière, A., von Schuckmann, K., Sallée, JB. et al. Robust acceleration of Earth system heating observed over the past six decades. Sci Rep 13, 22975 (2023). https://doi-org.insu.bib.cnrs.fr/10.1038/s41598-023-49353-1

Storto, A., Yang, C. Acceleration of the ocean warming from 1961 to 2022 unveiled by large-ensemble reanalyses. Nat Commun 15, 545 (2024). https://doi-org.insu.bib.cnrs.fr/10.1038/s41467-024-44749-7

Storto, A., L. Cheng, and C. Yang, 2022: Revisiting the 2003–18 Deep Ocean Warming through Multiplatform Analysis of the Global Energy Budget. J. Climate, 35, 4701–4717, https://doi.org/10.1175/JCLI-D-21-0726.1.

Von Schuckmann, K., Cheng, L., Palmer, M. D., Hansen, J., Tassone, C., Aich, V., Adusumilli, S., Beltrami, H., Boyer, T., Cuesta-Valero, F. J., Desbruyères, D., Domingues, C., García-García, A., Gentine, P., Gilson, J., Gorfer, M., Haimberger, L., Ishii, M., Johnson, G. C., Killick, R., King, B. A., Kirchengast, G., Kolodziejczyk, N., Lyman, J., Marzeion, B., Mayer, M., Monier, M., Monselesan, D. P., Purkey, S., Roemmich, D., Schweiger, A., Seneviratne, S. I., Shepherd, A., Slater, D. A., Steiner, A. K., Straneo, F., Timmermans, M.-L., and Wijffels, S. E.: Heat stored in the Earth system: where does the energy go?, Earth Syst. Sci. Data, 12, 2013–2041, https://doi.org/10.5194/essd-12-2013-2020, 2020b

Von Schuckmann, K., Minière, A., Gues, F., Cuesta-Valero, F. J., Kirchengast, G., Adusumilli, S., Straneo, F., Ablain, M., Allan, R. P., Barker, P. M., Beltrami, H., Blazquez, A., Boyer, T., Cheng, L., Church, J., Desbruyeres, D., Dolman, H., Domingues, C. M., García-García, A., Giglio, D., Gilson, J. E., Gorfer, M., Haimberger, L., Hakuba, M. Z., Hendricks, S., Hosoda,

S., Johnson, G. C., Killick, R., King, B., Kolodziejczyk, N., Korosov, A., Krinner, G., Kuusela, M., Landerer, F. W., Langer, M., Lavergne, T., Lawrence, I., Li, Y., Lyman, J., Marti, F., Marzeion, B., Mayer, M., MacDougall, A. H., McDougall, T., Monselesan, D. P., Nitzbon, J., Otosaka, I., Peng, J., Purkey, S., Roemmich, D., Sato, K., Sato, K., Savita, A., Schweiger, A., Shepherd, A., Seneviratne, S. I., Simons, L., Slater, D. A., Slater, T., Steiner, A. K., Suga, T., Szekely, T., Thiery, W., Timmermans, M.-L., Vanderkelen, I., Wjiffels, S. E., Wu, T., and Zemp, M.: Heat stored in the Earth system 1960–2020: where does the energy go?, Earth Syst. Sci. Data, 15, 1675–1709, https://doi.org/10.5194/essd-15-1675-2023, 2023.

GVAP-II

Trent, T., Schröder, M., Ho, S.-P., Beirle, S., Bennartz, R., Borbas, E., Borger, C., Brogniez, H., Calbet, X., Castelli, E., Compo, G. P., Ebisuzaki, W., Falk, U., Fell, F., Forsythe, J., Hersbach, H., Kachi, M., Kobayashi, S., Kursinski, R. E., Loyola, D., Luo, Z., Nielsen, J. K., Papandrea, E., Picon, L., Preusker, R., Reale, A., Shi, L., Slivinski, L., Teixeira, J., Vonder Haar, T., and Wagner, T.: Evaluation of total column water vapour products from satellite observations and reanalyses within the GEWEX Water Vapor Assessment, Atmos. Chem. Phys., 24, 9667–9695, https://doi.org/10.5194/acp-24-9667-2024, 2024.

ISCCP-NG

Heidinger, A.K. and co-authors, 2024: The Era of the GEO-RING: The Next Generation of the International Satellite Cloud Climatology Project (ISCCP-NG). BAMS, submitted August 2024.

BSRN

An incomplete list of publications which refer to BSRN data is available on the BSRN web page (https://bsrn.awi.de/other/publications/reviewed-scientific-papers-referring-to-bsrn/)

2.2.1 GDAP Rapporteurs Report

Panel: GEWEX Data and Analysis Panel (GDAP)
Rapporteur(s): Susanne Crewell, Richard Forbes and Maria Piles

Adherence to GEWEX and Panel's objective(s)

GDAP Panel objectives:

1. 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?"
2. 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.
3. Sponsor supporting ground-based references networks.
4. Trigger new international initiatives to support GEWEX science objectives and inform the research community at large."

The GDAP panel continues to adhere to both GEWEX and all the Panel objectives (above). The GDAP panel has a clear focus currently with the support of the BSRN radiation surface network (oversight of GPCC now handed to GHP), two previous data quality assessments (precipitation, clouds, both potentially to be revisited), two active data quality assessments (water vapor GVAP-II, Earth Energy Imbalance EEI) and two new initiatives (ISCCP-NG, convective/cloud tracking). There is a clear scope for the Panel, closing assessments once completed, initiating new assessments when needed, and moving on network responsibilities from GDAP when matured (GPCC).

Achievement of annual goals for this reporting period

- Provide expertise to support the analysis of satellite datasets:

  GDAP continues to support the GEWEX Integrated Product (ISCCP, GPCP, SRB, SeaFlux, and LandFlux) and next-generation satellite data products (ISCCP-NG, convective tracking).
- Oversee dataset assessments to provide critical uncertainty information for data records and identify gaps and future needs:

  Earth's Energy Imbalance (EEI) and GVAP-II water vapour assessments are ongoing, filling gaps in quantifying uncertainty in critical data; Potential for ISCCP-NG clouds assessment and activity on convection/cloud-tracking.
- Support ground-based networks:

  BSRN supported and data collected. GPCC now officially reporting to GHP.
- Act as an interface between GEWEX activities and datasets:

  Various activities are of common interest with PROES and other GEWEX panels (GLASS, GASS, and GHP). There was a GEWEX cross-panel meeting at the GEWEX OSC in July 2024 and in May 2025 there is a GDAP meeting in conjunction with UTCC-PROES.
- Represent GEWEX to agencies and the within the science community:

  In 2024, there was GDAP representation at the GEWEX Open Science Conference (OSC), NDAAC Annual Steering Committee, International Radiation Commission (IRC), AGU, EGU, and various science meetings and symposiums.

Major accomplishments and results in reporting period

- A new panel member (Hanii Takahashi) joined GDAP to maintain the Panel's demographic and topical diversities.
- In 2024, the EEI assessment team published a comprehensive inter-comparison of the TOA radiation budget, ocean heat content rate estimates from ocean in-situ temperatures and space geodesy (altimetry and space gravimetry) (Hakuba et al. 2024). The EEI assessment paper identified a group of OHU estimates based on satellite and in-situ data that agree on interannual variability and trend with the TOA radiation budget record from CERES. It also pinpointed systematic differences in the processes used to derive OHU estimates from in-situ data and from satellite data that are responsible for the large uncertainty range of in-situ-only OHU estimates.
- A paper on key results from G-VAP Phase II (Trent et al., 2024) has been published in ACP. Methods have been developed to estimate the clear-sky bias using reanalysis and GNSS data. Though the uncertainty of the bias estimates is larger than the actual bias, the bias estimates from the two different databases are in good agreement.
- A cloud tracking data intercomparison has been initiated as a new GDAP activity in collaboration with the AOS and INCUS science teams. ISCCP-NG prototype data is being used in the TOOCAN cloud tracking algorithm.
- The BSRN team published a best practices paper for ocean radiometric measurements in collaboration with OASIS and others in the ocean measurement community (Riihimaki et al., 2024). New data has been incorporated into the BSRN archive from 21 out of the 43 active stations.
- A "Best Practices for Product Assessments" document is being defined.

Arisen or noted science issues

It is of concern that the number of BSRN data being submitted has been decreasing over the last years, with many stations not submitting data and increasing numbers of inactive stations. The recommendation is to follow up on individual stations to explore the possibility of submission of existing data and greater timeliness.

Emerging Science

The cloud/convection tracking activity is helping to form a convection tracking community to unify and share tools and expertise between AOS, INCUS and GEWEX.

The next-generation GPCP V4 is being developed over the next five years (with a Beta product available in 2026). Compared to V3, this will improve the consistency and accuracy of satellite and gauge Analysis, increase duration (daily and sub-daily going back to 1983), increase resolution (from 0.5 to 0.1deg), and reduce latency (gauge assessment with ~2 weeks latency).

EUMETSAT is processing a 5-year ISCCP-NG L1g data set. As part of the ISCCP-NG, an initial assessment of cloud properties shows that an improved algorithm gives greater consistency with other cloud cover estimates. The TOOCAN cloud tracking algorithm is being applied to the ISCCP-NG GeoRing data to track deep convective systems.

Future plans

- The panel should start writing the first version of the synthesis report on the GEWEX EEI assessment activity in the coming two years.

- The panel will propose a common EEI dataset format, and an intercomparison is planned for the first full assessment. The panel is currently organizing a new EEI assessment workshop for spring 2025.
- There is a GVAP-II workshop meeting being planned for late 2025.
- A cloud tracking assessment, led by Hanii Takahashi, is an emerging activity that will be a promising addition to the GDAP portfolio. Convective tracking dovetails with the ISCCP-NG activity as a potential science application of the L1G product. It will also feature in future directions with the UTCC PROES project, led by the GASS Panel. A third Convection Tracking meeting is planned for 2026 as well as regular online meetings of the leads/sub-leads.
- ISCCP-NG: EUMETSAT plans to generate a 5-year ISCCP-NG L1g data set and host it with NOAA in a cloud service. ICWG is planning a cloud product comparison using the current ISCCP-NG L1g demo. This will help the community determine the requirements for cloudiness information from ISCCP-NG.
- The next GDAP meeting will take place 22-23 May 2025 in Paris in conjunction with a UTCC-PROES meeting (19-21 May).

Recommendations to Panel

1. Improve BSRN data availability
   - Follow up on inactive stations and explore the potential to restart data submission.
   - Explore possibilities of improved data timeliness, as currently it can take several years before data is submitted from many stations and more timely data is more likely to be used by the wider community.
   - There is a need to justify the (voluntary) efforts of contributors to continue to collect and provide data as part of BSRN. Find out how much the community is using the data. How many countries/institutions use the data? Can data downloads be monitored? Would an online survey emailed to contacts be feasible/useful? Could there be more use of the data with increased awareness - for example the data should be important for weather and climate model evaluation, and the solar energy community.
   - Follow-up on other potential ground-based stations with high-quality standards that could become BSRN sites – DoE, ACTRIS, GLAFO?
2. Increase community awareness of datasets and assessments
   - Find ways to increase community awareness of GDAP datasets, ease of access to datasets (e.g. BSRN) and dataset assessments (e.g. precipitation), e.g. publicize more at conferences. GDAP activities give a significant benefit to the modelling community and the climate record. It's important to maximize this, and it helps to provide ongoing justification for GEWEX activities.
   - Provide more targeted guidance (value-added interpretation) to different communities with different needs, e.g. highlighting strengths and weaknesses of precipitation products over ocean vs land; IMERG is good for extremes and GPCP is more appropriate for the climate record. Information is there in the detailed assessment reports but could be highlighted more prominently.
3. Explore opportunities for polar data and analysis

   Energy/water exchange in polar regions has had less attention in the community, largely due to sparser data and the difficulty of observing the polar environment (e.g., the GEO-Ring doesn't extend to the polar regions). Observing polar regions is clearly very relevant to support Arctic Policy. New missions like CIMR or CRISTAL from ESA and the European Commission will provide full sub-daily polar coverage. GDAP should consider opportunities for an activity to facilitate polar products,

particularly as a recent panel member has joined with polar experience. There are potential links with CliC here.

4. Explore the possibility of a ground-based weather radar activity

   There are many weather radar networks across the world, and although limited in coverage, they cover a significant part of the world's populated areas. GDAP should consider whether they could play a role in helping to share expertise/best practices for ground-based radar networks (e.g. precipitation estimation, quality control) across the world, building on the NEXRAD and OPERA experiences. An enthusiastic radar expert on the panel could be an initial step. There are potential links with GPEX (and GHP) here.

5. Consider extending assessments to the covariance of data products

   Consider future opportunities for a combined assessment of data products, e.g. radiation in the context of cloud regimes, cloud uncertainty variations by weather regime. This information is very useful for modelers for model evaluation and could provide further value from observational datasets where quality may vary with meteorological regime. Although there has been some activity on this, there may be other opportunities that arise.

6. Enhance links with other projects
   - Cloud tracking activity – this activity is appropriate for GSRM/km-scale simulations, and it is important to make the modelling community aware of what output is needed from the models to apply cloud tracking on model output (e.g. frequency of output, simulated satellite images). There are potential links with GASS/PROES activities here.
   - GASS and GDAP have mutual interests in process diagnostics and observations and should facilitate collaboration where appropriate, e.g. development of satellite simulators for GSRMs (global storm-resolving models), use of high-resolution satellite observations for evaluating GSRMs and studying convective organization.
   - Evapotranspiration – there was a GEWEX/GRP LandFlux activity 10 years ago (focusing on production of a multi-decadal global land-based surface flux data set) but is there an opportunity for a renewed assessment, perhaps linked with the GLASS panel? One possible approach is increased engagement with Fluxnet and with the International Soil Moisture Network (ISMN) projects.
   - Precipitation – ensure there are ongoing links with GPEX on precipitation datasets and assessment to ensure GPEX is complementary to GDAP activities.
   - Model evaluation - strengthen links with ESMO requiring datasets for model evaluation.
   - The EUMETSAT CM-SAF (Satellite Application Facility on Climate Monitoring) provides satellite-derived products and services for climate monitoring. This is very relevant for GDAP, and with the SAF's upcoming renewal it will be important to keep links with the SAFs and opportunities for product assessments.

7. Panel membership

   The GDAP panel already has a good diversity of people and expertise but could continue to look for opportunities for ground-based weather radar expertise and Southern Hemisphere representation.

Considerations for SSG

GDAP has highlighted concern of the lack of planned satellite missions for radiation and precipitation in the future (e.g. lack of CERES-like missions, precipitation-related missions after PMM). GDAP could feed into a wider GEWEX opinion statement raising concerns about the lack of future satellite missions relevant to observing the global energy and water cycles.

Additional Remarks

It is fully recognized that GDAP has limited resources and cannot do everything that is requested or recommended, but GDAP should continue to look for opportunities where it can make a difference and continue to focus on what it can do well.

We would like to express our thanks to the co-Chairs for their dedication to the GDAP panel and excellent work over the past 12 months to progress and develop GDAP initiatives for GEWEX.

2.3 GEWEX Hydroclimatology Panel (GHP)

Full Panel Name (Acronym) : GEWEX Hydroclimatology Panel (GHP)
Reporting Period : 01 January - 31 December 2024
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 – 2024
Venkataraman Lakshmi, 2023 – Present
Santosh Pingale, 2022 – Present
Andreas Prein, 2019 – Present
Joshua Roundy, 2020 – Present
Vidya Samadi, 2019 – Present
Anna Sörensson 2021 – 2024
Ivana Stiperski, 2019 – 2024
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 from an integrated perspective.

List of Panel Goals

During 2024, the GHP achieved several goals:

- Update the Terms of Reference for Panel Members
- Update the guidelines for new Regional Hydroclimate Projects (RHPs) and Cross-Cutting activities (CCs)
- Establish the guidelines for new Networks (not available before)
- Revise and approve the Scientific and Implementation Plan for the ANDEX RHP
- Revise and conditionally approved AsiaPEX Science proposal
- Revise and conditionally-approve the Scientific Proposal of the River Experiment (RivEX) CC
- Revise and conditionally-approve the Scientific Proposal of the Global Groundwater Network (GGN)
- Held the 2024 GHP Annual Meeting in Sapporo-Japan

List of 2 to 3 Key Results

- New activities: ANDEX became a mature RHP, RivEx became a new conditionally approved CC, and GGN became a new conditionally approved Network
- Consolidated Terms of Reference and New Activity Guidelines

Other Science Highlights

- Important scientific advances in many of the mature and initiating RHPs
- More interactions between other WCRP activities and the GHP
- During 2024, two the Members left the Panel (Anna Sörensson and Ivana Stiperski). The GHP Co-Chairs are advancing in the interview of potential New Members, including a new female ECR.

Panel Activities during Reporting Period

List of Panel Activities and Main Result

GWF

GWF is currently winding down and its projects are completing their work and deliverables over 2024-25. A major synthesis effort is underway to compile outcomes in a user-question centric framework, which will be completed in 2025.
GWF is now under transition to the Global Water Futures Observatories (GWFO), which supports operations of its 64 instrumented basins, lakes, rivers, and wetlands, 15 deployable observation systems, and 18 state-of-the-art water laboratories that provide urgently needed scientific data to deliver flood, drought, and water quality solutions.
During the reporting period GWF has conducted, initiated and finalized several activities, including (1) Weaving Science: Stories of Research Engagement, (2) GWF Briefing Book – Realizing Global Water Futures: a Summary of Progress in Delivering Solutions to Water Threats in an Era of Global Change, (3) Wastewater Surveillance for Sars-Cov-2 Virus Particles, (4) Women + Water Lecture Series and Community, (5) GWF Planetary Water Prediction Initiative (PWPI), (6) Central Asian GEF/UNDP/UNESCO project, and (7) Yukon, NWT and Canadian Rockies Observations and Forecasting.

Baltic Earth

Baltic Earth key activities include: (1) Preparation of the next Baltic Earth Phase and Science Plan 2024/2025, (2) Restructuring and transition from Grand Challenges to new and updated Research Topics, and (3) Transition preparations for the International Baltic Earth Secretariat to Institute of Baltic Sea Research, Warnemünde, Germany and Institute of Oceanology PAN, Sopot, Poland.
Baltic Earth also ran 3 main educational activities: (1) Baltic Earth Winter School IOPAN Sopot, Poland, 18-22 March 2024 https://baltic.earth/winterschool2024, (2) Baltic Earth Summer School Askö, Sweden, 25 Aug-2 Sep 2024 https://baltic.earth/summerschool2024, and (3) International Baltic Earth Master Course on “Climate of the Earth system”, University of Rostock, Germany, 2023/2024 https://baltic.earth/news/112116/index.php.en.
The activity also conducted 5 major dissemination activity: (1) Special Issue in Oceanologia on the 4th Baltic Earth Conference Jastarnia “Assessing the Baltic Earth System”; finalized: 11 papers https://www.iopan.gda.pl/oceanologia/66_1; (2) Special Issue in Estuarine Coastal and Shelf Science on River Mouth Systems and Marginal Seas – Natural Drivers and Human Impacts; almost finalized (15 papers) https://www.sciencedirect.com/special-issue/10HQ49HMPFK; (3) Oxford Research Encyclopedia “Climate of the Baltic Sea”, overview papers; 21 published or in review/accepted; 25 more proposed, closing by the end of the year https://oxfordre.com/climatescience/; (4) Frontiers in Earth Science Research Topic on 5 th Baltic Earth Conference in Jurmala, Latvia: New Challenges for Baltic Sea Earth System Research Call for Papers open: Submission deadline: 30 March 2025 https://www.frontiersin.org/research-topics/67058/new-challenges-for-baltic-sea-earthsystem-research; and (5) Baltic Earth-HELCOM Climate Change Fact Sheet 2024 https://helcom.fi/wp-content/uploads/2024/10/Baltic-Sea-Climate-Change-FactSheet_2024.pdf.

TPE-WS

TPE-WS have finished the maintenance of the “TPE Integrated Three-dimensional Observation and Research Platform”. The instruments of eddy covariance and radiation have been calibrated, and the

data set of land-atmosphere interaction process have been collected. A network of Raindrop spectrometers (10 stations) has been constructed for monitoring rain drop sizes, frequency and amounts over the Tibetan Plateau. A dual band Scintillometer for measuring turbulent heat flux over the high-elevation lakes has been installed in May 2024. Several international meetings and workshops have been organized/attended by the activity.
TPE-WS also published a good number of papers on the processes of land-atmospheric interaction processes (e.g., [Yuan et al., 2024] published a 37-year dataset (1982–2018) of monthly ET covering the TP and [Chen et al., 2024c] found that, the evapotranspiration (ETa) on the TP exhibited a significant increasing trend of about 8.4± 2.2 mm per decade from 1982 to 2018, which is approximately twice the rate of the global land Eta trend), boundary layer processes (e.g., [Wang et al., 2024] investigated the convective boundary layer height during the pre-monsoon/monsoon/post-monsoon periods using radio sounding data and reported the seasonal variation of CBLH over the TP. 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). For climate change, [Xu et al., 2024] suggested that by 2100, even under a low-emissions scenario, the surface area of endorheic lakes on the TP is expected to increase by over 50% (approximately 20,000km^2), with water levels rising by about 10 meters relative to 2020 levels. This expansion would result in a fourfold increase in water storage compared to the period between the 1970s and 2020. The expansion of lakes is primarily driven by increased lake water inputs from two sources: higher precipitation and increased glacier meltwater, both of which are linked to climate change.
During September to November 2024, professor Tandong Yao and the STEP group have taken the world's longest ice core (324m) in the world's mid to low latitude glaciers in Purog Kangri, Shuanghu county, Tibet. The ice core can help for study the climate and environment change over the past tens of thousands of years.

ANDEX

ANDEX added two review papers on advances in atmospheric modeling and is planning a hydrological modeling review for 2025. Summaries of selected representative articles selected from the monthly reference list are made available at ANDEX website.
ANDEX participated of a recent review paper (Gascoin et al. 2024) that provided an assessment of the currently available satellite datasets for monitoring mountain snow cover variations. They recognized a clear knowledge gap for climate, ecology and water resources applications associated with these datasets, and identified three salient topics where recent developments in snow remote sensing and data assimilation can lead to significant progress. These include snow water equivalent, high resolution snow-covered area and long-term snow cover observations including snow albedo. The need for sustained institutional support was identified as a crucial element for this kind of improvements and future developments.
ListANDEX continues to be an important communication and dissemination channel between ANDEX members, JovenANDEX and the Scientific Committee. Being a space for discussion, networking and dissemination of relevant calls for our community.
The JovenANDEX program with the current goals and activities have been presented in several meetings and institutional events, including (1) Youth and Innovation: Solutions are in the Mountains, and (2) Young Voices of the Mountains.

H2US

Two cross-project proposals, and one convergent proposal are being pursued; one NASA TWSC Proposal was Funded. An Expression of Interest was submitted Schmidt Sciences– still awaiting a response. An NSF R2I2 Proposal is being developed, which emanated from the H2US community. A proposal to NASA TWSC was funded: in collaboration with the AGCI. Through Schneider, H2US is a Co-PI for a project to identify observing system water cycle priorities and to inform the next Decadal Survey (Water component).

Coordination with other related projects Building ally-ships and with CONVECT (U-AZ/Steve Koch), NASA-ARID/Andrew Feldman, and NASA-Harnessing the Heartland & WHyMSIE /Bob Swap).

AsiaPEX

HiPRECS continues data acquisition and obtained data in 2024. They got data of record-breaking Nepal extreme rainfall event on 27-28 September. It is now under analysis. They presented three papers in GEWEX/OSC.
SOHMON project continues data collection from rain gauges, AWSs, and disdrometers (Murata et al. 2024). They collected intensive simultaneous radio sonde observations at three locations in India and Bangladesh. And it further extending collaboration for the hydroclimatological research over the NE Indian subcontinent.
South Asian meteorological Association (SAMA) Weekly Online Lecture Series on (1) Atmospheric Physics, (2) WRF modelling System with Hands-on practical, (3) Satellite Meteorology, and (4) Radar Meteorology for 16-20 weeks were conducted. Nearly 1500-2000 people registered for the lecture series from about 60 countries across the world.

Central Asia Initiative

The Central Asia RHP initiating workshop was held in Osh, Kyrgyzstan (https://www.gewexevents.org/meetings/3rd-workshop-central-asia/) and a summary report was written. It was distributed through GEWEX, and a shorter summary appeared in a GEWEX quarterly newsletter.
The team published the article, Brody, M., M. Kulikov, S. Orunbaev, and P. van Oevelen, 2024: The Global Energy and Water Exchanges (GEWEX) Project in Central Asia: The case for a regional hydroclimate project. Adv. Atmos. Sci., https://doi.org/10.1007/s00376-023-3384-2. This article lays out the need and potential approaches to a Central Asia Regional Hydroclimate project.
The RHP core team has been created. Current co-leads are Michael Brody, George Mason University and Sagynbek Orunbaev, American University of Central Asia in Bishkek, Kyrgyzstan. Other members are from Kyrgyzstan, Uzbekistan and Kazakhstan.
The team gave presentations and posters at the GEWEX Open Science Conference in Sapporo Japan. Brody gave an introduction to the proposed RHP to the GEWEX irrigation cross-cut group. There are some potential collaborations that will come from this with a group at NASA Goddard. Brody also gave a presentation for a CARIN (Central Asia Regional Information Network) webinar
Several team members attended AGU and gave presentations or posters.
The team submitted a proposal to DoE ARM – but did not make the selection.

INARCH

The INARCHs Common Observing Period Experiment (COPE) has finished the data collection phase and is moving into Analysis and modeling activities. These will directly address several INARCH science questions.

TEAMx

The Coordination and Implementation Group (CIG) continues to oversee TEAMx activities and meets approximately every other month. Three new members joined the CIG: Nikolina Ban (University of Innsbruck) and Sven Kotlarski (Meteo Swiss) replaced Elisa Palazzi in representing the mountain climate community and Günther Zängl (DWD) strengthened the involvement of the operational weather services.
After finalizing the Numerical Modeling Plan, the Numerical Modeling Committee was dissolved and reconstituted with the leaders of ongoing TEAMx model intercomparison studies, including intercomparison studies on thermally driven flows, cold-air pools, and orographic convection. Several Task Teams have been involved in the planning of different TEAMx Observational Campaign (TOC) activities. The Task Team Implementation Plan has drafted a first version of the Implementation Plan that outlines the IOP types targeted during the TOC and the IOP decision process. The Task Team Flight

Planning is developing flight plans for the aircraft operations and is facilitating the contact with air-traffic control.
The Task Team Data Management has finalized the TEAMx Data Management Plan and is coordinating activities regarding near real-time exchange of instrument information and quick looks during the TOC.
The Task Team UAS is coordinating airborne measurements with UAS. Further TOC planning activities and joint research activities are taking place in six Working Groups on 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. The Mountain Boundary Layer working group is subdivided into sub-WGs focusing on thermally driven winds and transport, cold-air pools, near-surface observations, free valley atmosphere observations. Another sub-WG, belonging to the Surface-Atmosphere Exchange-WG has been established focusing on Glacier-Atmosphere Interactions.

River Experiment (RivEx)

The main activity during the first months of the RivEx initiative consisted in monthly meetings of the co-leads and quarterly meetings with the community to identify the main goals of the project, prepare its diffusion among worldwide researchers potentially interested and establish a work plan for the coming years.

Floods

Discussions on the Floods CC study regions, data, models, and other approaches were discussed during several online meetings. The critical challenges of moving this initiative forward is resources. Plan of actions were also discussed during in-person meeting in the 9th GEWEX Science Conference in Japan.

PannEx

The FAIR NEtwork of micrometeorological measurements continued within PannEx. Budget is available only for organizing meetings and short-term scientific missions.
A summer school was organized on micrometeorological measurements and applications together with the 7th PannEX Meeting in Budapest, Hungary.
The webpage of PannEx was updated: https://pannex.org/.

Global Groundwater Network (GGN)

The steering Group was initiated and has been meeting monthly to initiate the GGN. The team held their first in person network workshop at GEWEX Conference in Sapporo with ~25 attendees. They collectively identified key challenges for hydrogeology and groundwater modeling in ESM and GEWEX. In addition, the GGN team developed the required GEWEX documentation and officially commenced the Network. Finally, GGN held a session and splinter meeting at the IAH World Groundwater Congress (Davos, September 2024), launched a website for the network and started mailing list, has recruited interested participants to the network, and contributed an article to the 4th Quarterly GEWEX newsletter.

GRDC

The GRDC team updated existing stations and obtain data from 41 countries.
Also, contributed to the WMO State of the Global Water Resources Report 2023, provided data for more than 700 stations.
Updated the BALTEX stations draining into the Baltic Sea, now 768 stations are in the up-to-date dataset (extended BALTEX).
New cooperation with University of Stuttgart, Institute of Geodesy, Prof. Nico Sneeuw. Potential hosting of these two datasets as an addition to GRDC.
Elmi, O., Tourian, M. J., Saemian, P., & Sneeuw, N. (2024). Remote Sensing-Based Extension of GRDC Discharge Time Series-A Monthly Product with Uncertainty Estimates. Scientific Data, 11(1), 240. doi.org/10.1038/s41597-024-03078-6

Saemian, P., Elmi, O., Stroud, M., Riggs, R., Kitambo, B. M., Papa, F., Allen, G. H., and Tourian, M. J.: Satellite Altimetry-based Extension of global-scale in situ river discharge Measurements (SAEM), Earth Syst. Sci. Data Discuss. [preprint], https://doi.org/10.5194/essd-2024-406, in review, 2024

Participation in IAHS "ReHydrate" working group, part of the IAHS HELPING – Science for Water Solutions decade. The project focuses on digitization of various historical hydrological data.

GPCC

GPCC has advanced in data acquisition activities, e.g. at bilateral meetings of other meteorological services with DWD and WMO meetings (SERCOM-3, INFCOM-3). In addition, GPCC participated in training activities (international courses at DWD, workshops organized by WMO), conferences and workshops. This data center has advanced on further integration of data from open data portals

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

GWF

GWFO is now officially lunched. GWFO aims at (1) providing unique water data of interest to characterizing and monitoring the water conditions of Canadian river basins, (2) contributing to a critical baseline of water data to the benefit of multiple users, (3) supporting the data collection from, and analyzing of water from the network of instrumented water observing sites, and (4) adhering to the principles of open access. The vision is to operate a national water observatory consisting of a network of instrumented water observing sites, supported by deployable observing systems and major laboratories, that provides open access water data and the necessary infrastructure to collect supplementary data, which informs the development and testing of water prediction models, monitors changes in water sources, underpins diagnosis of risks to water security and helps design solutions to ensure the long-term sustainability of Canadian water resources.

ANDEX

OBSERVATORY OF SCIENTIFIC KNOWLEDGE ON CLIMATE CHANGE, an initiative led by ANDEX and the Geophysical Institute of Peru (IGP), with the support of the Peruvian Ministry of Environment, provides scientific support to various public management documents. Currently, the Observatory (https://cienciaclimatica.igp.gob.pe/) hosts more than 800 interpretations on topics related to climate change, contributing to the updating of the Regional Climate Change Strategies in the regions of Junín, Puno and Tacna. At the national level, it has integrated scientific contributions in the 4th National Communication on Climate Change, the National Adaptation Communication and the Loss and Damage Assessment. This collaboration is expected to expand in 2025 to other Regional Governments and public management documents at the national level.
Likewise, the IGP's Climate Science Observatory received the Good Practices in Public Management 2024 certification in the category of Transparency and Access to Information, highlighting its valuable work in the interpretation and dissemination of scientific knowledge on climate change. This recognition underscores its essential role in facilitating access to scientific information and supporting decision-making to address climate change in Peru.

The freely available "Observatorio Andino" platform (https://observatorioandino.com/nieve/) continues to be the main source for monitoring the daily snow cover variations in the central Andes of Chile and Argentina. The site has received more than 7000 visitors since its publication in late 2021 and is expected to grow in content and geographical extent in the near future.
On December 14 and 15, 2024, we participated of the 1st meeting of the AccelNet project, "Andean Climate Change - Observations, Research and Discovery (ACCORD)". This project is funded by NSF and will allow an unprecedented cooperation among research groups and networks working in different regions across the Andes, thereby providing new opportunities for synergies and unrivaled new insights

into the changing characteristics of the hydroclimate impacts that are increasingly affecting Andean societies.

IANIGLA-CONICET and ANDEX scientists have also recently started participating of the EU Commission HORIZON project entitled “Unlocking the full potential of Copernicus data and infrastructure to improve meltwater monitoring in the Andes (SNOWCOP)”. Project partners include EURAC (Italy), MRI (Switzerland), University of Chile, IANIGLA-CONICET (Argentina), and private consulting firms from Belgium.
At the end of May 2024, ANDEX scientists gathered in Pisac, Cusco, Peru, to participate in a training session on inter- and transdisciplinary science. At the end of the meeting, ANDEX received an invitation from Mater Iniciativa to visit the facilities of Milcentro in Moray, Cusco. This visit marked the beginning of various exchanges, discussions, and project ideas involving hydroclimatic science, agriculture, water security, and food security. Mater was created in 2013 with the aim of connecting the Peruvian gastronomy with science, the arts, humanities, and other disciplines, developing a method that observes beyond the obvious, fostering exchange. The platforms of Mater for showcasing this approach are Central and Kjolle restaurants in Lima, MIL in Cusco, and MAZ in Tokyo.
In April 2024 the International Joint Laboratory Altiplano (LMI Altiplano by its acronym in Spanish and French) was launched. The LMI (https://lmialtiplano.com) is a transdisciplinary research network focused on the study of the links between environmental and human health, and the use of water resources, in the context of mining, urban pressure and global change in the Altiplano. It expects to answer major socio-environmental issues and provide adaptation strategies and capacity building. In addition, in October 2024 ANDEX launched a project focused on the hydroclimatology of the Pilcomayo River basin in Bolivia, Paraguay, and Argentina. Funded by the French government in collaboration with Bolivian institutions, this project aims to analyze the evolution of rainfall and extreme events in historical records and future projections. Additionally, the impact of Amazon deforestation on the hydroclimate of the Pilcomayo River will be analyzed using numerical simulations conducted under the AMANECER-MOPGA project (PI: JC Espinoza).

AsiaPEX

Comprehensive intensive field campaign for atmosphere-ocean interaction was conducted over the western North Pacific Ocean (Philippine Sea) for June to July 2024. Utilizing Research Vessel (R/V) Mirai of Japan Agency for Marine-Earth Science and Technology (JAMSTEC), a number of instruments were applied for the observations of northward shift of ITCZ and passing tropical cyclone. This activity was led by Dr. Satoru Yokoi, JAMSTEC.
SOHMON project conducted a field campaign focused on the process of the production of high most static energy airmass over the Northeastern Indian subcontinent. It conducted a series of four times daily radiosonde observations spanning the region from Bangladesh to Assam, India. Main observation period was from 25-27 May 2024.
SOHMON project launched new project on collaborative modeling initiative for pre monsoon severe storms and lightning predictions (Mondal et al. 2024a) collaborating with Indian and Bangladesh researchers.
A workshop on the adaptation to the climate change in South Asian countries is planned on 14-15 or Mar. 2024 at Kathmandu hosted by colleagues in Tribhuvan University.

INARCH

The COPE initiative is INARCHs latest new project/activity. This is a major effort, is globally unique and novel, and will produce a world-class set of new observations and data, model application and comparisons, and new insights that will have tremendous scientific value.

TEAMx

Seven new TEAMx projects have started since the beginning of 2024: Georg Wohlfahrt (University of Innsbruck), FWF: Empowering plant carbonyl sulfide uptake as a proxy for gross primary productivity; Christophe Brun (Université Grenoble Alpes), CNRS/INSU: Profiling of the turbulent boundary layer using a 3D pitot probe in katabatic winds on a steep slope. Implications for numerical modelling and the definition of laws of the wall; Miguel Teixeira/Paul Williams (University of Reading), Leverhulme Trust: A new diagnostic for fluid flow instability and turbulence generation; Stefano Serafin (University of Vienna), FWF: Demonstrating Parameter estimation with Ensemble-based Data Assimilation for Boundary-Layer modelling over mountains; Lindsey Nicholson (University of Innsbruck) and Tobias Sauter (Humboldt Universität Berlin), FWF/DFG: Glacier-Space: Assessing the resilience and vulnerability of mountain ice masses (GlacierSpace); Matthias Aichinger-Rosenberger (ETH Zurich), MeteoSwiss: Machine-learning based Advancement and assessment of GNSS Interferometry Reflectometry for Complex terrain in Switzerland; Manfred Dorninger (University of Vienna) and Windpuls GmbH, FFG: Evaluating a novel sensor for meteorological applications. In addition, as part of TEAMx-UK, four research projects will be funded: Andrew Orr (British Antarctic Survey): Flow Dynamics, Scale Interactions and Mountain Waves for TEAMX-UK; Helen Dacre (University of Reading): Turbulence Evaluation in Complex Terrain using TEAMx Observations; Andrew Ross (University of Leeds): Orographic convection; Ian Renfrew (University of East Anglia): Orographic Flow Representation in the Alps at Multiple scales.

RivEx

Augusto Getirana, Co-I on “SWOT Contribution to the Understanding of Global Terrestrial Water Storage and Fluxes Through a Multi-Satellite Data Assimilation Framework” supported by SWOT Science Team. Cedric David, PI on “Revealing the Speed of River Flow Waves”, supported by NASA SWOT Science Team. Cedric David, Co-I and JPL lead on “NASA WaterView”, supported by NASA Earth Science to Action.

GRDC

Contributing to and collaborating with ROBIN: Reference Observatory of Basins for INternational hydrological climate change detection. UKCEH.
Contributing to and collaborating with RivEx: The River Experiment initiative: Advancing global surface water science for local societal benefits (David et al.).

GPCC

The GPCC is involved in a German Government activity “Water Security in Southern Africa” (WASA) project Co-HYDIM-SA. Existing drought monitoring systems should be enhanced and extended by sub-seasonal and seasonal forecasts using drought indices adapted to the needs in this region. After the project, the drought monitoring and prediction system should be operated and maintained by the local authorities

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

GWF

GWF held a GWFO workshop on observations and data and discussed next steps. They continue to seek funding to support scientific activities, building on GWFO facilities.

ANDEX

The ANDEX Science and Implementation Plan has been submitted to GEWEX for review. The proposed activities and expected outcomes, detailed in Table 1 of the Science Plan and Annex 1, address six of the seven GEWEX imperatives (i.e., datasets, analysis, processes, modeling, applications, and capacity

building), presenting an innovative proposal to achieve these key scientific objectives in the Andean region.

AsiaPEX

An experimental real time event attribution system on northern Japan region is now developing based on recent paper Tamura and Sato (2024). This will further be a technical base to be applied to other regions through AsiaPEX capacity development activities. This activity is led by Dr. Tomonori Sato, Hokkaido University.

Central Asia Initiative

Regional downscaling modeling is beginning with development of data sets for the simulations. It will take approximately 6 months for the first phase. A main objective includes better understanding of future precipitation.

The steering group is now planning the summer school for September 2025. Including location, topics and potential invitees.

INARCH

Special Issue of Hydrological Processes, "Improving measurement, understanding, and prediction of alpine cold regions hydrological processes and their sensitivities to global change": INARCH has proposed a special issue of HP to gather scientific outcomes from COPE and other recent activities and as a contribution to initiatives such as the United Nations International Year for Glaciers' Preservation and the UN Decade of Action on the Cryospheric Sciences. This issue will be open through 2025.

TEAMx

Eight new TEAMx (pre-) proposals have been submitted to national funding agencies and are awaiting funding decisions or will be (re) submitted shortly: Andreas Platis (University of Tübingen) and Manuela Lehner (University of Innsbruck), submitted to DFG/FWF: Horizontal shear production over complex terrain - uncrewed aircraft measurements of turbulence for model parameterization; Vinzent Klaus (BOKU University) and Jan Handwerker (KIT), submitted to DFG/FWF: Thunderstorm Initiation and Intensification in Alpine Terrain Observed by Polarimetric weather radars; Courtney Strong (University of Utah), submitted to NSF: Multi-scale Transport and Exchange Processes in the Atmosphere Over Mountains; Nora Helbig (Eastern Switzerland University of Applied Sciences), submitted to SNF: Along-valley winds: Unveiling the impact of topography-driven three-dimensional radiative transfer Anahi Villalba Pradas (Charles University), submitted to GACR: Unravelling Sub grid-Scale Orography Effects on Composition in the Free Atmosphere; Chantal Staquet (Université Grenoble Alpes) and Julian Quimbayo-Duarte (Goethe University Frankfurt), submitted to ANR/DFG: Cold-air pool modelling and pollution control in complex terrain; Philipp Gasch (KIT), submitted to DFG: Linking valley flow and vertical exchange in complex terrain; Stefano Serafin (University of Vienna), Marco Arpagaus (MeteoSwiss), Annika Oertel (KIT), Mathias Rotach (University of Innsbruck) and Jan Keller (DWD), to be submitted to FWF/DFG: A Grey-zone Ensemble Analysis for TEAMx.

Floods

The Floods CC team will focus on strategies and directions to go during the AGU in-person meeting.

GGN

GGN aims to reach out directly to key hydrogeologists and groundwater modelers to recruit leads for GGN subgroups, which will be organized around key challenges (target: 3-4 sub-groups this year). In addition, the team aims to launch working groups on key challenges and recruit additional members to each group, host a splinter meeting EGU, and host an in person GGN Meeting (target: in person meeting in the fall, ~20 participants including the steering group, subgroup leads and additional interested participants).

GPCC

IAFE-KI_Precip is a GPCC internal project with the Deutscher Wetterdienst (national meteorological service, which hosts the GPCC). This project aims to develop artificial intelligence (AI) based tools for automatic detection and correction of wrong precipitation values. Currently, more than 2% of all added data records to the GPCCs data collection are checked and, if needed, corrected by manual activities. Tools developed in this project should process the majority of this flagged values (the easy cases), so the manual interaction is only needed for the difficult cases.

Science Issues and Collaboration during Reporting Period

Contributions to Developing GEWEX Science and the GEWEX Imperatives.

a. Data Sets

GWF

Complete data is available at https://gwf.usask.ca/outputs-data/data.php
GWFNet metadata catalogue can be found at https://gwfnet.net/.

TPE-WS

Four datasets have been published in the Tibetan Plateau Datacenter:

1. [Yuan et al., 2024]: a 37-year dataset (1982–2018) of monthly ET components (soil evaporation Es, canopy transpiration Ec, and intercepted water evaporation Ew) using the MOD16-STM (MOD16soil texture model). The model integrates updated soil properties, meteorological data, and remote sensing datasets.
2. [Chen et al., 2024a]: ground-based microwave radiometer (MWR) network to monitor the troposphere over the Tibetan Plateau (TP) including temperature and humidity profiles in the troposphere, a region that has been under continuous observation only recently.
3. [Ma et al., 2024]: dataset covering 12 stations' in-depth, hourly measurements of surface energy balance components across the Tibetan Plateau (TP) from 2005 to 2021. The dataset includes three primary categories of observations: meteorological gradient data (met), soil hydrothermal data (soil), and turbulent flux data (flux).
4. [Fan et al., 2024]: a comprehensive cryosphere–hydrometeorology observation network in the basin since 2014. At present, the network consists of 21 automatic rain gauges, 22 soil freeze–thaw monitoring stations, 4 automatic weather stations (AWS), and a 50-m gradient meteorological tower with an eddy covariance system. In particular, the 18 sites, located in remote areas without public networks, are equipped with new- generation BeiDou-3 communication terminals that enable the observations to be easily, safely, and reliably read and quality controlled in near–real time from offices in the city or at home.

ANDEX

Daily Snow Cover Area (SCA) information derived from the MODIS sensor for the main watersheds in central Chile and central-western Argentina and for the period 2000-present, continue to be available free of charge at the "Observatorio de Nieve de Argentina y Chile" (https://observatorioandino.com/nieve/). This work is part of Leandro Cara PhD thesis in Mendoza, Argentina, under the direction of Dr. Mariano Masiokas from IANIGLA-CONICET in Mendoza, Argentina, and collaborations from Drs. Ricardo Villalba (also IANIGLA), Rene Garreaud, and Duncan Christie (CR2, Chile).
A PhD thesis was started in 2023 under the support of ANDEX in the Unit Leader Climatology, University of Bern, by the PhD candidate Adrian Huerta (Peruvian) and under the advice of Pr. Stefan Brönnimann (U of Bern) and Waldo Lavado (SENAMHI, Peru). This thesis aims at the weather reconstruction of daily precipitation for South America since the early 1950s. These results would be a major input for the ANDEX initiatives in the region, as part of the project PrecipANDEX. Several

meetings were carried-out during the Annual Meeting in Lima, and by video conferences with ANDEX members of different countries with the aim of updating precipitation time-series in Chile, Argentina and Bolivia. A first paper is currently in redaction (Huerta et al. in preparation).

AsiaPEX

A quasi-global daily precipitation data with moderate spatial resolution, GPC/m Global Precipitation Climatology, is being developed by Dr. H. G. Takahashi, Tokyo Metropolitan University (Takahashi, 2024). This dataset has been produced by machine learning from 1979 to 2020.
A historical global historical reanalysis (1850-2015), OCADA, using 60- km AGCM and surface pressure observations (Ishii et al. 2024). As an extension to HadEX3, a sector-relevant climate extremes indices are developed by Dunn et al. (2024). For these datasets, activity from AsiaPEX was led by Dr. Hisayuki Kubota, Hokkaido University. Declaro and Kanae (2024) developed surface water monitoring by remote sensing using multiple satellite images from optical and SAR satellites. It significantly improves median revisit intervals globally.

INARCH

INARCH datasets are available at https://inarch.usask.ca/datasets-outputs/mountain-hydrometeorological-data.php.
Operational and experimental snow observation systems in the upper Rofental: data from 2017 to 2023, https://doi.org/10.5194/essd-16-3579-2024.
Also see https://doi.org/10.5880/fidgeo.2023.037 and https://fileshare.uibk.ac.at/f/c93698d938874011aa2e/?dl=1.

TEAMx

Instruments have been deployed at several sites that will run continuously throughout the TOC. This includes, for example, multiple wind lidars in the Inn Valley (deployed by MeteoSwiss, GeoSphere Austria, KIT, and the University of Innsbruck) and a radar at Rittnerhorn in the Alpine Crest Target Area (deployed by KIT). Several test measurements have been conducted during the summer, including aircraft flights over the Alpine Crest and Inn Valley Target Areas by KIT and TU Braunschweig. DWD has started to deliver high-resolution forecast runs for the TEAMx domain with a grid spacing of 500 m. Radiosounding, Doppler wind lidar, and microwave radiometer data from the TOC will be sent to the GTS to make the data available for (real-time) data assimilation in numerical models.

GRDC

GRDC now includes 10,381 in situ river discharge station-based data (13.11.2024). Regularly updated.

GPCC

HOMPRA-Europe, Version 2, was released in November 2024. This data set is based on homogenized station data for Europe. The homogenization was done with a fully automatic procedure. The data set covers the period 1951-2015 and is based on 7916 stations, which have a temporal coverage of at least 80% in this period.

b. Analysis

GWF

GWF has a major focus on describing and analyzing observed variations, trends, and extremes (such as heat waves, floods, and droughts) in water and energy related quantities. Development of a comprehensive listing of all activities and outputs are underway.

TPE-WS

[Guo et al., 2024] enhances the understanding of moisture dynamics in the central Himalayas and highlights the need to account for anomalous circulation patterns when using δ^{18}Op data for climate reconstructions. The findings emphasize the importance of considering seasonality and circulation anomalies when interpreting isotopic records in regions like the Himalayas, where moisture sources can vary significantly. In the pre-monsoon season, δ^{18}Op values are generally high, influenced by westerlies and local moisture. However, some abnormally low δ^{18}Op values are observed during periods of higher precipitation. These low values are linked to moisture transported northward from the Bay of Bengal and the Arabian Sea, driven by anomalous atmospheric circulations, such as quasi-anticyclones, anticyclones, and westerlies troughs. The size and location of the quasi-anticyclone can significantly affect the magnitude of the δ^{18}Op decrease. In contrast, during the monsoon season, δ^{18}Op values are lower, influenced by the Indian summer monsoon and convection. This leads to heavier rainfall and the depletion of δ^{18}O, resulting in lower δ^{18}Op values.
[Yuan et al., 2024] compared the MOD16-STM ET results with in situ measurements, demonstrating a low root mean square error (RMSE) of 13.48 mm per month, a mean bias of 2.85 mm per month, a coefficient of determination (R^2) of 0.83. The estimated annual average ET for the entire TP (elevations above 2500 meters) is approximately 0.93 $\times 10^3$Gt per year. Soil evaporation (Es) is the predominant contributor to ET on the TP, accounting for 84% of the total ET. The study identifies a significant upward trend in ET in most central and eastern parts of the TP, with an increase of 1–4 mm per year ($p<0.05$). In contrast, the northwestern part of the TP experienced a downward trend with rates between -3 and 1 mm per year from 1982 to 2018. On average, ET on the TP has increased by approximately 0.96 mm per year over the past 37 years, likely driven by warming and wetting climate conditions in the region.

ANDEX

The ANDEX community carries out virtual discussions and Analysis of different hydroclimatic phenomena and related impacts on the society in the region. For this, ListANDEX is becoming an excellent tool. For example, community has discussed recently: - Snow and rain in Chile - Floods in Rio Grande do Sul - Climate change, biodiversity and interactions in the Andes course - Call for collaboration for the AndAMOS project of the transversal line of modeling - Inclusive language - Altiplanic winter - Monthly summary of the readings uploaded to the ANDEX website.

AsiaPEX

Musaid et al. (2024) analyzed upper tropospheric and lower stratospheric circulations over the Asian monsoon region to elucidate characteristics of dynamic and thermodynamic structures of Asian summer monsoon anticyclone (ASMA).
Role of tropical disturbances along the monsoon trough on 2022 Pakistan floods has been analyzed and impacts of synoptic and intraseasonal variabilities and interannual variabilities associated with ENSO cycle are elucidated by Takahashi (2024).

INARCH

INARCH members have carried out many Analysis at the mountain research basins and mountain regions more broadly. INARCH has quantified the sensitivity of mountain snow hydrology regimes around the world. INARCH continues to examine the performance of alpine snow models in simple alpine environments by comparison of model outputs to diagnostic measurements. See https://inarch.usask.ca/science-basins/cope.php#Modellingsoftwaretools.

TEAMx

A paper has been published that summarized the key findings from the TEAMx pre- campaign 2022, which reveal the wind, temperature, and humidity structure in the Inn Valley Target Area. Analysis of a previous dataset collected at the Hintereisferner Glacier is ongoing, which will inform a future

measurement campaign focusing on the land-atmosphere exchange over the glacier, which will be conducted in the framework of TEAMx. The ongoing analysis of data collected during test measurements at the beginning of 2024 on a slope site in the Inn Valley Target Area by the Université Grenoble Alpes forms the basis for an extended experiment during the upcoming winter EOP of the TOC.

GPCC

The GPCC provided Analysis of precipitation and its anomalies for a number of high-level WMO report: State of the Global Climate in 2023, State of the Climate in Asia in 2023, State of the Climate in Southwest Pacific in 2023, State of the Climate in Africa in 2023, State of the Climate in Europe in 2023, BAMS State of the Climate in 2023, WMO Climate Policy Brief 2024.

c. Processes

GWF

Several GWF projects are focused on improving process understanding and parameterizations, e.g., in prairie, mountainous, and agricultural landscapes, ecological feedbacks and wildfires.

TPE-WS

[Liu et al., 2024] focused on improving the simulation of snow albedo and snow cover over the Tibetan Plateau using the Weather Research and Forecasting Model (WRF) with an improved snow albedo scheme. This improvement is attributed to local optimization of snow-age parameters and explicit consideration of snow depth in the albedo scheme. Compared to the previous model, the improved model reduces overestimated albedo by 0.13–0.27. The bias range is reduced to ±0.08, with a mean relative bias decrease of 70%. The spatial correlation coefficient significantly increases by 0.03–0.39 (mean: 0.13). The most significant improvements in albedo estimation are observed in regions with deep snow cover, attributed to the parameter optimization related to snow albedo decay. Shallow snow-covered regions show less improvement, indicating that the model improvements are more effective in areas with thicker snow. The improved model results in a decrease in false-alarm rate by 0.03 and an increase in overall accuracy and equitable threat score by 0.04 and0.03, respectively. The model shows equivalent improvements in albedo and snow-cover estimates at both 1-km and 5-km grid spacing, particularly over the eastern Tibetan Plateau.

AsiaPEX

Takaya et al. (2024) studied the process of remote energy exchanges, which is caused by snow cover change and impacted on surface air temperature in remote region through the atmospheric processes associated with snow cover change on a sub-monthly timescale.

INARCH

Significant advancement in alpine hydro-meteorological process understanding and representation in models has been achieved by INARCH.

TEAMx

The TEAMx Implementation Plan includes a description of the processes of interest that will be targeted during the TOC, in particular during Intensive Observational Periods. The list of processes of interest was compiled by the TEAMx PIs. During the 4th TEAMx Workshop in November 2024, a number of TEAMx PIs presented their ongoing and planned TEAMx research and the processes they are studying, including, e.g., slope winds, convection initiation, turbulence, and mountain waves.

d. Modeling

GWF

Hydrological, ecological, land surface and atmospheric model development and application is central to GWF's mission. Examples include CRHM, MESH and CHM.

TPE-WS

[Zhang et al., 2024] examined the influence of lake size and soil moisture (SM) on the development of lake breezes and moist convection over land adjacent to lake susing large-eddy simulation (LES) experiments. The simulations focus on understanding how different factors, such as lake size and soil moisture, affect the dynamics of lake-breeze fronts (LBF) and the onset of deep moist convection (DMC). Here are the key findings: As the lake diameter increased from 20 km to 50 km and 70 km, the maximum precipitation increased by 71.4% for a 50 km lake and by 1.29 times for a 70 km lake. Reasons for increased precipitation are stronger and broader updrafts and moisture transport. When the lake diameter increased from 20 km to more than 50 km, DMC occurred 20 minutes earlier. This early onset is likely due to broader shallow convective clouds in large-lake simulations and the larger vertical velocity of cloud-initiating parcels, which facilitate the faster development of convection.

ANDEX

From ANDEX's Transversal Line about hydroclimatic modelling, we are working on the AndAMOS project as a candidate for the "Flagship Pilot Study" of CORDEX (PI: Lluis Fita). The AndAMOS project aims to improve knowledge of the Andean climate and provide useful data for impact studies and decision-making. The project proposes building on "experiences" co-produced by modelers, impact researchers, and decision-makers. The proposed methodology is innovative, as it involves selecting case studies (specific short-duration events) to evaluate the capability of current modeling and analysis tools to meet the ideal data needs for case studies and decision-making processes.
A group of ANDEX scientists conducted a review of more than 200 scientific papers with the objective of synthesizing the numerical simulations used to understand various atmospheric processes that affect the meteorology and climate of the Andes. This review was published in two articles in the scientific journal Frontiers Earth Sciences: Atmospheric Science.

INARCH

The network has developed and advanced the next generation of alpine meteorological and hydrological models, conducted earth system model intercomparisons, proposed new algorithms for modeling and has applied its models to examine sensitivity and responses to climate and land cover change. See https://inarch.usask.ca/science-basins/models-downscaling-tools.php. See new paper documenting the newest version of openAMUNDSEN model: https://doi.org/10.5194/gmd-17-6775-2024, plus the Git Repository with everything important to download, install and run the model: https://github.com/openamundsen/openamundsen.

TEAMx

Seven European weather services (DWD, MeteoSwiss, GeoSphere Austria, Météo- France, Met Office, CNR-ISAC, and the Croatian Meteorological Service) are planning to provide high-resolution forecast runs for parts of the TOC. The simulations with grid spacing down to 500 m will be used to guide IOP planning and for model evaluation. Model intercomparison studies are ongoing focusing on thermally driven winds and transport, cold-air pools, and orographic convection. Further intercomparison studies, including a potential intercomparison of the semi-operational forecast runs in the previous point, are being developed.

e. Application

GWF

A rapid analysis and attribution study of the 2021 B.C. flooding event was carried out and published in the journal Weather and Climate Extremes.

AsiaPEX

Hokson and Kanae (2024) developed a new statistical method to identify similar tropical cyclone tracks introducing the Sinkhorn distance, which can be better than conventional Fuzzy C Means (FCM) clustering algorithm to discern similar TC tracks and elevate the accuracy of TC rainfall predictions. Wahba et al. (2024) evaluated the efficacy of machine learning approaches to generate flood susceptibility maps (FSMs). It was shown that the ANN-MLP and SVR models achieved notable accuracy for production of FSMs.

INARCH

The INARCH team has used the Integrated High Mountain Observation and Prediction Systems (IHMOPS) to improve our scientific understanding, and evaluate observed changes, data and models around the world. The models are being used to estimate the sensitivity of the high mountain cryosphere and hydrology to climate change. See an example application of both the data and the model from the Rofental, Austria, including satellite image comparison: https://doi.org/10.1002/hyp.15279.

TEAMx

The current focus of TEAMx is on planning, securing funding, and deploying instrumentation for the experimental (observational and modelling) activities. These activities are being developed with applications in mind. Several European weather services have expressed their interest in using data collected during the TOC to evaluate their models.

GRDC

Freshwater Fluxes into the World's Oceans - https://fwf.bafg.de.
Major River Basins of the World - https://mrb.grdc.bafg.de.

f. Technology Transfer

GWF

GWF works with 558 partner and user groups to deliver knowledge, scientific advancements, and new tools for managing water risks. In particular, GWF has strong engagement with provincial and federal governments to improve water prediction and forecasting at the national scale.

AsiaPEX

Team of Dr. Tomonori Sato in Hokkaido University developing an experimental real time event attribution system based on Tamura and Sato (2024), which can be a technical base to be applied to other regions through AsiaPEX capacity development activities.

INARCH

INARCH will work with mountain communities and regions and national governments to develop plans to predict future water scenarios, build capacity, enhance forecasting systems, answer questions on water futures and evaluate the sustainability of proposed water management solutions.

TEAMx

The TEAMx Numerical Modeling Plan, which was published this year, includes 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. At the same time, a variety of cutting-edge modeling studies (1-m large-eddy simulations; 1km climate

simulations; idealized, semi-idealized and real-terrain simulations) will be used to investigate processes that cannot be measured directly, to extend the coverage of instrumentation, and to conduct careful experiments to investigate the controls on particular processes. One of the ongoing TEAMx projects (alpineVISION) is a collaboration between the University of Vienna and the company Windpuls GmbH who have developed a novel sensor that is being tested for meteorological applications in the framework of TEAMx.

PannEx

PannEx advanced in organizing a training school to provide knowledge and technology. The main local organizer was Tamás Weidinger.

GPCC

The GPCC is involved in the operation of the Meteorological Data Collection Centre (MDCC) of the European Commission Copernicus Emergency Management Services (CEMS). GPCCs experience in the processing of meteorological data is used in this activity.

g. Capacity Building

GWF

During its operation, GWF has recruited and trained 2,020 highly qualified personnel.

ANDEX

From October 21 to 24, in response to the requirements of the NUREX project by the WMO in Andean countries, a scientific writing workshop was held at SENAMHI, Peru, led by JC Espinoza. The workshop lasted 16 hours and was attended by 15 young scientists from SENAMHI. This initiative serves as a starting point to align the common objectives of ANDEX and the WMO in the region. JovenANDEX continues to promote the development of its Journal Clubs, which address key topics in the hydroclimatic field. The activity of the existing clubs during the year 2024 is detailed below: Cryosphere and Water Resources: Coordinated by Fabian Drenkhan, has held six (6) sessions during 2024. ○ Continental Hydrology: Coordinated by Lucía Cappelletti, Sly Wong and Eduardo Noriega has held seven (7) sessions in 2024. ○ Climate System Modeling: Coordinated by Juan Pablo Sierra, has conducted five (5) sessions during the same period. In addition, coordination has begun for the creation of a new Journal Club entitled “Statistical Methods in Hydroclimatology”, which will be coordinated by Rocío Balmaceda from Argentina and Santiago Mendoza from Bolivia. ListANDEX remains a key platform for communication and exchange among ANDEX members, JovenANDEX, and the Scientific Committee. It serves as a hub for discussion, networking, and sharing important opportunities relevant to our community. During this year, there was an exchange with the Scientific Committee regarding Gender and Diversity. Therefore, a webinar is being planned for the beginning of 2025, with the participation of experts on this topic.

AsiaPEX

SAMA Weekly Online Lecture Series on (1) Atmospheric Physics, (2) WRF modelling System with Hands-on practical, (3) Satellite Meteorology, and (4) Radar Meteorology for 16-20 weeks were conducted. Nearly 1500-2000 people registered for the lecture series from about 60 countries across the world.

INARCH

INARCH will work with communities and regions to develop plans to predict future water scenarios, build capacity, enhance forecasting systems, answer questions on water futures and evaluate the sustainability of proposed water management solutions.

TEAMx

TEAMx is applying to become a World Weather Research Programme (WWRP) partner project. The Project Coordination Office has provided several letters of endorsement for TEAMx projects.

PannEx

PannEx activities have involved PhD students and young scientists, who were participants of the training school.

GGN

Open GHP, GEWEX to hydrogeologists and groundwater modelers.

GPCC

Zora Schirmeister and Markus Ziese (both GPCC) contributed to training for the meteorological services from the countries of the Arab League, organized by WMO, about development and usage of climatological data sets. Also, GPCC developed a contribution to the "Numerical training course" at DWD by lesson about quality control, processing and gridding of precipitation 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?

GWF

Integrated Modelling Program for Canada (IMPC: https://gwf.usask.ca/impc/) project and core modelling team (https://gwf.usask.ca/core-modelling/) address this topic.

TPE-WS

[Xu et al., 2024] Used a combination of field surveys, remote sensing data, and numerical modeling, the study projects future changes in lake surface area, water levels, and volumes, and evaluates the risks posed by these changes to infrastructure, human settlements, and ecosystems. By 2100, even under a low-emissions scenario, the surface area of endorheic lakes on the TP is expected to increase by over 50% (approximately 20,000 km²), with water levels rising by about 10 meters relative to 2020 levels. This expansion would result in a fourfold increase in water storage compared to the period between the 1970s and 2020. The expansion of lakes is primarily driven by increased lake water inputs from two sources: higher precipitation and increased glacier meltwater, both of which are linked to climate change. Without mitigation measures, the expansion of lakes is expected to submerge critical infrastructure, including more than 1,000 km of roads, approximately 500 settlements, and around 10,000 km² of ecological areas, such as grasslands, wetlands, and croplands.

AsiaPEX

Declaro and Kanae (2024) developed surface water monitoring by remote sensing using multiple satellite images from optical and SAR satellites. It significantly improves median revisit intervals globally.

INARCH

INARCH 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

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.

GGN

Groundwater is the largest terrestrial freshwater reservoir by far, yet it remains very poorly quantified and highly uncertain. Predicting temporal changes in groundwater storage is even more challenging and often oversimplified or ignored in earth systems models. Our GGN seeks to bring together hydrogeologists and groundwater modelers with the GEWEX community to improve groundwater representation and address this issue.

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?

GWF

GWF Integrated Modelling Program for Canada (IMPC: https://gwf.usask.ca/impc/) project and core modelling team (https://gwf.usask.ca/core-modelling/) address this topic.

TPE-WS

[Chen et al., 2024c] showed that From 1982 to 2018, the ETa on the TP exhibited a significant increasing trend of about 8.4 ± 2.2 mm (10 years) -1 , which is approximately twice the rate of the global land ETa trend, which was around 4.3 ± 2.1 mm (10 years) -1 .
[Chen et al., 2024c] projects that the increase in ETa will continue to accelerate the water cycle across the TP until 2100. This means that as temperatures continue to rise, and the cryosphere melts further, evapotranspiration will increase, which could lead to significant changes in the water balance and regional hydrology.

ANDEX

Huayao Observatory (Huancayo, Peru) of the Instituto Geofísico del Perú (IGP) is currently proposed as a possible GLAFO-GEWEX station. Exchanges between IGP, ANDEX and GEWEX started in 2022. During the Atmospheric Physics workshop, the ANDEX Scientific Committee visited the Huayao Observatory.

AsiaPEX

Takaya et al. (2024) remote energy exchanges through the atmospheric processes associated with snow cover change on a sub-monthly timescale. It further confirmed that S2S dataset underestimates the impact of snow cover change due to some deficiencies in the models.

INARCH

INARCH is focused 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 and stream flow synthesis. Important progress has been made, and many scientific publications have resulted.

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 TOC. 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 the water vapor transport within the boundary layer, as well as exchange at the top of the boundary layer and with the surface below.

GPCC

GPCCs data sets help to monitor the flux of water (precipitation) from the atmosphere to the land surface. The long time series allow the analysis of temporal and spatial variability of these fluxes.

3. Precipitation Extremes*:*

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

GWF

Short-Duration Extreme Precipitation in Future Climate project https://gwf.usask.ca/extreme-precipitation/ and Climate-Related Precipitation Extremes: https://gwf.usask.ca/extremes/index.php address various aspects of precipitation extremes.

TPE-WS

[Chen et al., 2024b] focused on the Yarlung Zsangbo Grand Canyon (YGC) as an important pathway for water vapor transport from southern Asia to the Tibetan Plateau (TP). This area exhibits one of the highest frequencies of convective activity in China, and precipitation often induces natural disasters in local communities, which can dramatically affect their livelihoods. This team subsequently established a comprehensive observation system of land–air interaction, water vapor, clouds, and rainfall activity in the YGC. This paper introduces the developed observation system and summarizes the preliminary results obtained during the first two years of the project. Using this INVC observation network, herein, they focus on the development of rainfall events on the southeastern TP. This paper helps to monitor geohazards in the key area of the Sichuan–Tibet railway, which traverses the northern YGC. The observation datasets will benefit future research on mountain meteorology.

ANDEX

Several studies were published in 2023-2024 regarding extreme events in the Andean regions. Indeed, extreme droughts were reported in the Amazon basin (Espinoza et al., 2024) and the Altiplano region (Gutierrez et al., 2024).

AsiaPEX

Jeon et al. (2024) examined the sub-regional characteristics of extreme precipitation during summer, decomposing contributions from dynamic and thermodynamic terms. AsiaPEX members contribute to a sector-relevant climate extremes indices developed by Dunn et al. (2024).
Franke et al. (2024) carefully analyzed extreme precipitation events evaluated in station data, observation-based rainfall datasets like APHRODITE and ERA5-Land, and those reproduced by global high-resolution (25km) Community Earth System Model (CESM) for South Korean region, suggesting characteristics of future precipitation extreme projections and needs for advancement of observation-based precipitation extreme datasets.

INARCH

This is a fundamental aspect of INARCH with respect to mountain precipitation with a fundamental question being '*What is the phase of precipitation?'* and '*How is it changing from snowfall to rainfall and how are rainfall extremes changing in high mountains?*'. This includes rain-on-snow events, which can result in extreme flooding in mountain environments.

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 TEAMx-endorsed project 'kmMountains '

uses high-resolution climate simulations (of the order of 1 km grid spacing) to improve understanding of precipitation and extreme events over mountainous regions, in particular the effects of continued atmospheric warming.

GPCC

GPCCs data sets with daily temporal resolution helps to investigate spatial and temporal patterns of precipitation extremes and their changes. As larger changes are expected on sub-daily scales, GPCC wants to collect and process sub-daily precipitation observations in future. Furthermore, GPCC collects daily data to extend data sets with daily resolution further back.

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?

GWF

Integrated Modelling Program for Canada (IMPC: https://gwf.usask.ca/impc/) project and core modelling team (https://gwf.usask.ca/core-modelling/) address this topic.

INARCH

INARCH contributes through its work at 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.

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 feedbacks.

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)?

GWF

GWF's network of observatories provide detailed measurements of surface energy and water fluxes.

TPE-WS

[Wang et al., 2024] studied the atmospheric boundary layer (ABL) on the Tibetan Plateau (TP), which is important to understand surface heat and moisture balances, as well as weather and climate change on the TP and surrounding areas. The paper investigated the convective boundary layer height (CBLH) during the pre-monsoon, monsoon, and post-monsoon periods using radio sounding data. As the monsoon advanced, the spatial distribution of CBLH shifted from high in the south and low in the north to low in the south and high in the north. During this transition, although there was a decrease in downward shortwave radiation in regions significantly influenced by the monsoon (southern and central TP), the net radiation increased or remained constant in most regions. In the southern and central TP, both sensible heat flux and CBLH decreased, accompanied by a substantial drop in the contribution ratio (CR) of sensible heat flux to convective boundary layer (CBL) development. The CRs decreased to 25.13% and 31.30% at two stations significantly affected by the monsoon, respectively. In contrast, in regions less affected by the monsoon (northern TP), sensible heat flux didn't exhibit a significant decrease, and CBLH increased. The CR of sensible heat flux to CBL development at one

station less affected by the monsoon was high, reaching 58.92%. 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. 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.

INARCH

INARCH mountain research basins provide exemplary datasets for characterizing mountain boundary layer meteorology in otherwise data-sparse regions of the world.

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.

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

GWF studies using the WRF atmospheric model has shed important insights on circulation controls.

TPE-WS

[Yu et al., 2024] Against the traditional view, a recently published theory argued that isotope ratios are higher in convective precipitation but lower in stratiform precipitation and proposed that isotope ratios reflect rain type proportions. This theory has been widely cited despite some early reservations. Whether the theory represents a faithful reflection of signals of water isotope ratios remains unclear. Here, the study reassesses its validity from different timescales and broader observations from the pan tropics. Unexpectedly, the findings contradict the theory on daily, monthly, and even annual timescales. Pantropical precipitation isotope ratios remain strongly correlated to convection intensity but are independent of rain type proportions because stratiform precipitation isotope ratios cover a large range of values. The study found that the theory has many serious weaknesses related to preferential data selection and suggest that new theories need to be validated at more locations on different timescales before gaining widespread acceptance.

ANDEX

Recent studies from ANDEX scientists analyzed future projections of the main atmospheric circulation patterns (Agudelo et al., 2024), including in the framework of the RegIPSL modeling team and ANDEX. A particular focus on the Amazon-Andes transition region was given in the study Gutierrez et al. (2024a), where the ability of CORDEX models was analyzed, particularly in reproducing spatial rainfall distribution and annual cycle in this challenger region. A team of ANDEX scientists reviewed more than 200 papers to synthesize numerical simulations of atmospheric processes affecting Andean weather and climate. The results were published in two papers in Frontiers in Earth Science. More details, see above. On the other hand, Milla et al. (submitted) investigate changes in atmospheric circulation patterns related to the lengthening of the dry season in the South American Altiplano. Additionally, using the high-resolution WRF model, Gutierrez et al. (submitted) analyze the influence of Andean topography on the optimal precipitation zone (Quincemil, Peru) in the Andes-Amazon transition region.

AsiaPEX

Jeon et al. (2024) examined the sub-regional characteristics of extreme precipitation during summer, decomposing contributions from dynamic and thermodynamic terms. It was shown that characteristics of contributions from terms are different across sub-regions.

Musaid et al. (2024) analyzed dynamic / thermodynamic balance of upper tropospheric monsoon anticyclone over the Asian monsoon region.
Synoptic-scale heavy precipitation events in the future were analyzed using 720-year ensemble datasets simulated by the Non-hydrostatic Regional Climate Model with a 5 km resolution (Kawase et al. 2023). It projected decreases of frequency in tropical cyclone induced events and increases by Baiu front and extratropical cyclones (Sugimoto et al. 2024).

INARCH

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

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.

GPCC

GPCCs Full Data Monthly dataset covers the 1891-present period. It allows the investigation of correlations with external drivers like ENSO.

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

GWF studies using the WRF atmospheric model has shed important insights on land-atmospheric interactions.

TPE-WS

[Chen et al., 2024c] From 1982 to 2018, the ETa on the TP exhibited a significant increasing trend of about 8.4 ± 2.2 mm (10 years) -1, which is approximately twice the rate of the global land ETa trend, which was around 4.3 ± 2.1 mm (10 years) -1. 53.8% of the ETa increase on the TP is attributed to higher temperatures, which has led to increased evaporation and transpiration. 23.1% of the increase is linked to rising soil moisture, driven by the combination of warming, melting cryosphere (e.g., glaciers), and increased precipitation. [Li et al., 2024] This study quantitatively evaluates the carbon dioxide (CO_2) sink intensity of a large saline lake (area > 2000 km2) and a small saline lake (area 1.4 km2) on the Tibetan Plateau (TP), alongside an alpine meadow, by analyzing their net ecosystem exchange (NEE)figures obtained by eddy covariance (EC) measurements. It found that Tibetan Plateau saline lakes serve as CO_2 sinks. Larger saline lakes exhibit enhanced CO_2 sink capacity during cool, non-icing periods while small lakes do less. Ice barrier and chemical processes mainly control CO_2 uptake in saline lakes.

ANDEX

In 2024 ANDEX science obtained a Project (PROCIENCIA-Peru) to implement the ORCHIDEE-WRF model in the Peruvian Geophysical Institute (IGP) in Peru (PIs: Ken Takahashi (IGP/ANDEX), Jhan-Carlo Espinoza (IRD/ANDEX) and Jan Polcher (CNRS/IPSL/GEWEX)). This project has a focus on future projections of the water cycle in the Andes due to climate change and Amazon deforestation. Climate simulations of a coupled ORCHIDEE-WRF model, including floodplains parametrization is available for the entire South America at 20 km of horizontal resolution for the period 1996-2020. The study of Bedoya-Soto and Poveda (2024) investigates how water vapor originating from land surfaces in the Colombian Andes contributes to the region's rainfall, a process known as moisture recycling. Using a high-resolution (0.25°) modeling approach (WAM-2) driven by ERA-5 data from 1980 to 2020, the

authors quantify and trace the flow of continental moisture through different timescales, from monthly and seasonal to annual and interannual (ENSO) variations. The study also demonstrates that continental moisture sources expand spatially during transitional seasons (spring and fall), coinciding with the interaction between orographic features and low-level jets that carry moisture. On interannual scales, both the sources and receptors of recycled moisture are influenced by ENSO phases, underscoring the importance of large-scale climate variability in shaping regional hydrological processes.

AsiaPEX

Research on the response of snow cover to climate change conducted by Blau et al. (2024) shows highly complex patterns. It revealed regional characteristics of impact of climate change on snow cover in different regions. It was shown that the response of snow cover to climate change. Takaya et al. (2024) applied Liang–Kleeman information flow analysis to identify "cold spots" where snow cover conditions actively influence surface air temperature on a sub-monthly timescale.

INARCH

Improved computational capacity, geospatial intelligence and new and improved modeling tools developed in INARCH 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 hydrometeorological, hydrological and hydro glaciological process studies that are conducted there.

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 investigates the surface energy balance closure in complex terrain and its implications for energy and carbon budgets. The TEAMx Unicorn project uses 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. The TEAMx project 'GlacierSpace' and further activities in the Glacier-Atmosphere Interactions subgroup of the Surface-Atmosphere Exchange WG addresses the turbulent exchange over glaciers. Plans exist to increase soil moisture monitoring in TEAMx target areas. The year-long TEAMx Observational Campaign has an Extended Observation Period in Winter as well as in Summer.

GGN

Groundwater plays an important role in land surface-atmospheric interactions, yet these connections are not well quantified in models. GGN is working to identify the key challenges that need to be addressed to better capture groundwater connections to land and atmosphere across spatial 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?

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 CORDEX-RCMs in the Andean region, including spatio-temporal rainfall patterns (Gutierrez et al., 2024.), SAMS representation (Olmo

et al., 2022) and SAMS projections regarding climate change scenarios (Agudelo et al., 2023). In addition, various members of ANDEX, led by P. Arias (Colombia), have submitted a paper titled “How well do CMIP6 models simulate key boundary conditions affecting South American climate? Insights for regional modeling efforts”. This study evaluates 57 models from the sixth phase of the Coupled Model Intercomparison Project (CMIP6) in their simulation of various spatial patterns and circulation features over South America (Arias et al., submitted).

AsiaPEX

Highly complex response of snow cover to climate change revealed by Blau et al. (2024) will evaluate the extent to which the climate change affects regional water availability including regions of North Asian and High Mountain Asia.

INARCH

This is a focus for 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.

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.

GPCC

The GPCC recently released an updated version of the homogenized precipitation analysis for Europe (HOMPRA-Europe, Version 2). Due to the homogenization of the used station data, it 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 focusses on landcover change (i.e. glacier loss, forest and vegetation change, land and water management) in cold regions, which impact the water cycle and the flow of rivers originating in mountain and cold regions.

AsiaPEX

Methods proposed by Declaro and Kane (2024) to enhance temporal resolution of surface water monitoring will facilitate utilization for surface water management.

INARCH

INARCH focusses on land cover change (i.e. glacier loss, forest and vegetation change) in mountain regions, which impact the mountain water cycle and the management and flow of rivers originating in mountain regions.

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 georeferenced 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.

GGN

Groundwater abstraction and conjunctive use of groundwater and surface water have had dramatic impacts on watersheds around the world. In many locations groundwater use has already decreased streamflow and in some cases converted perennial streams to ephemeral streams. Representing human abstraction in groundwater storage estimates and projections is one of the science challenges that the GGN is discussing.

GPCC

In general, GPCCs data sets can be correlated with land-use information to investigate the impact on land-use changes, e.g. deforestation, on precipitation totals and extremes. Care has to be taken, as not all GPCC data sets are free of artificial trends, which could cause spurious correlation.

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

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

ANDEX

IANIGLA-CONICET members of ANDEX, in collaboration with colleagues from ANDES C2H and IGE-UGA from Grenoble, France, conducted during 2024 an extended field campaign to northern and southern Patagonia. They visited consolidated study sites at key glaciated areas and installed new equipment and hydro-meteorological sensors at new selected locations along the Andes. These activities are part of an ongoing effort to strengthen the scientific and institutional bonds to improve our understanding and monitoring of glaciological and hydroclimatic variations in remote region.

AsiaPEX

Blau et al. (2024) revealed regional characteristics of impact of climate change on snow cover in different regions. It was shown that the response of snow cover to climate change, which affects regional water availability in surrounding regions, exhibits high spatial heterogeneity and nonlinearity.

INARCH

The coupled water and energy cycle is intrinsic to cold regions hydrology that is the core of INARCH. As climate warms, there is further decoupling of snow and hydrological regimes, resulting in increased variability in stream flow.

TEAMx

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

GGN

Dynamic groundwater surface water interactions play a key role in the stream flow variability and response to extreme weather events. Better representation of dynamic groundwater processes in earth systems models (the focus of the GGN) can be especially beneficial for improving forecasts of extreme events and systems undergoing change (challenges).

GPCC

The GPCC provides data sets covering long periods (Full Data Monthly: 1891-2020 (to be extended further), HOMPRA-Europe: 1951-2015, Full Data Daily: 1982-2020 (to be extended further)). Those can

be used to analyze variability and trends in precipitation at different scales, from global scale down to grid cell size. Care has to be taken as not all of these data sets are based on homogenized data, which could indicate wrong trends.

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

GWF

Ongoing science questions:

- 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?

TPE-WS

- How the land-atmosphere interaction over the lake region or over the heterogeneous mountainous region will impact on regional cloud or precipitation events over the TP?
- What will such effect change under the continuous warming and wetting over the TP?
- How is the CO2 flux change in the future and what are the dominant factors for the long-term trend over the different landscapes of TP?

H2US

- How are the water towers (aka in the mountains) of the western U.S. changing?
- How are these changes compounding to create impactful extremes (especially with respect to precipitation)?
- Recognizing that we are now in the Anthropocene, how do we include humans in our understanding of natural systems and build these capabilities into our predictive tools?

AsiaPEX

- Evaluation and projection of past and future extreme precipitation frequency covering all AsiaPEX region in multiple spatio-temporal scales with uncertainty estimation.
- Clarifying multiple scale interactions among subsystems and external climate systems such as ENSO through solving complex land surface atmosphere interaction.
- How can we organize collaborative field campaign with high scientific impact by participation of many field projects under the post covid situation?

INARCH

See INARCH proposal for a second phase, 2021-2026, for details. There will be multiple hypotheses that we want to test with the combination of sites and models that INARCH can work with in COPE: https://inarch.usask.ca/science-basins/phase-ii-science-plan-goals.php.

TEAMx

Given the specific focus of TEAMx on mountain weather and climate, one possible research focus for the future 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 the how climate projections for mountain areas depend on the resolution of climate models (esp. 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 the 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.

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 this might be different in the combined flood generation mechanisms across the coastal, urban, and rural settings?
- How do changes in 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?

GGN

Better quantify the role of groundwater and human water use in the water and energy balance from the continental to the global scale.

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 Climates 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. Our focus is on cold regions and high mountain regions as headwaters for major river systems of the world.

ANDEX

In September 2024, Eleonora Gonzalez, former ANDEX coordinator, started working with RIfS International Project Office. This proximity to RIfS gives us a strong possibility of collaboration with this project. In addition, members of ANDEX and JovenANDEX are part of My Climate Risk Hub CONICET - Argentina (https://sites.google.com/view/mcrhubconicet/p%C3%A1gina-principal?authuser=0).

H2US

The activity is in dialogue (occasional) with the Digital Earth and Global Precipitation Experiment Lighthouse Activities.

AsiaPEX

Results of Franke et al. (2024), Sugimoto et al. (2024) on future extreme precipitation events contribute to the 'My Climate Risk' project under the Light House Activities.
The 2nd Joint Workshop on the A3 Foresight Program: "Networking Climate Change Hubs for Promoting Future Earth over Northeast Asia" was held on 18-20 Dec. 2023 and was summarized in Yuan et al. (2024). Participants from South Korea, Japan and China shared and discussed their recent

research progresses in the area of climate change, monsoon, extreme events, climate–aerosol interactions, climate projections, and climate impacts over Northeast Asia. It facilitated the cooperations in Future Earth activities among the scientists in Northeast Asia.

INARCH

INARCH'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 onward delivery of, an integrated capability for quantitative observation, explanation, early warning, and prediction of Earth System change on global and regional scales, with a focus on multi-annual to decadal timescales. Our focus is on high mountain regions as headwaters for major river systems of the world.

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) 42 project partners (including universities, research institutes and weather services) from 13 countries and over 340 scientists from over 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.

Floods

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

PannEx

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).

Cooperation with other WCRP Projects, Outside Bodies and Links to Applications

GWF

- GWF supports and provides leadership to the International Network for Alpine Research Catchment Hydrology (INARCH), which is a GEWEX cross-cutting project to better understand alpine cold regions hydrological processes, improve their prediction, and find consistent measurement strategies.
- GWF and INARCH contribute to Intergovernmental Hydrological Programme (IHP), providing leadership (through the Canadian National Committee for IHP (CNC-IHP)), guidance (design of IHP's water security and climate change strategy, IHP IX), and scientific contributions.

- A GWF 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 21st to be International Glacier Day. GWF provides leadership and direction on awareness efforts and science for 2025.
- GWF helped guide a resolution to expand the glacier year to a decade and focusing on science rather than geographical regions, https://www.wcrp-climate.org/news/wcrpnews/2201-un-resolution. UNESCO is the lead agency and GWF provides support and scientific contribution.
- GWF has formal linkages to WMO through the Study Group on WMO Cryosphere Crosscutting Functions: Global Cryosphere Watch (SG-CRYO), and GWF co-organized and co-chaired the High Mountain Summit at WMO headquarters in Geneva, Switzerland in October 2019. The Summit outcomes were a call for integrated observation-prediction and services systems in high mountains around the world – something GWF is helping to implement in Canada and globally through its leadership of the World Climate Research Programme's International Network for Alpine Research Catchment Hydrology and the INARCH Common Observing Period Experiment (COPE) of 38 high mountain basins around the world.
- GWF has strong connections with the Chinese Academy of Sciences and the TPE program, with collaborative activities including joint experimental and field programs, student and faculty exchanges, and other connections. TPE is another GEWEX RHP in the Himalayas and Tibetan Plateau and has close links with GWF and a formal memorandum of understanding signed in 2018.
- GWF is the Canadian node partner of SWFP. Contributions include leadership of important Canadian and international research initiatives focusing on water resources and climate change in cold regions, and with linkage to INARCH, a working group on Climate Impacts on Global Mountain Water Security has been formed.
- GWF partners with the UK's GW4 WSA on sharing experiences and opportunities in stakeholder engagement, research and training, and global approaches to addressing water challenges and water security.

Baltic Earth

Contribution to the JPI Oceans and JPI Climate Knowledge Hub on Sea Level Rise, participation in two review articles:

Melet,et el., 2024: Sea Level Rise in Europe: Observations and projections, in: Sea Level Rise in Europe: 1st Assessment Report of the Knowledge Hub on Sea Level Rise (SLRE1), https://doi.org/10.5194/sp-3-slre1-4-2024, 2024.

Jiménez, J. A., et al. 2024: Sea Level Rise in Europe: Knowledge gaps identified through a participatory approach, in: Sea Level Rise in Europe: 1st Assessment Report of the Knowledge Hub on Sea Level Rise (SLRE1), https://doi.org/10.5194/sp-3-slre1-3-2024

Participation to the CLIVAR/CORDEX joint Task Force on Regional Ocean Projections (since 2024).

ANDEX

As described above, from October 21 to 24, in response to the requirements of the NUREX project by the WMO in Andean countries, a scientific writing workshop was held at SENAMHI, Peru. In addition, thanks to the collaboration between ANDEX and SENAMHI, Peru, a paper was published in 2024 about the variability and future projections of the wet season in Peru (De la Cruz et al., 2024).
In December 2022, the UN General Assembly adopted the resolution to declare 2025 as the International Year of Glaciers' Preservation (IYGP 2025), accompanied by the proclamation of March 21st of each year as the World Day for Glaciers starting in 2025. The International Year and World Day for Glaciers aim to raise global awareness about the critical role of glaciers, snow and ice in the climate system and 2024 GHP – ANDEX Working Group (Project) Report Page 11 of 15 the hydrological cycle, and the economic, social and environmental impacts of the impending changes in the Earth's

cryosphere, as well as to share best practices and knowledge in this regard and in addressing issues related to accelerated melting of glaciers and its consequences. Various members of ANDEX are part of the organization of the IYGP 2025, including the Advisory Board and different Task Forces specifically created for this event. We are aiming to integrate various activities of the ANDEX program with those pertaining to the IYGP 2025, including the ANDEX annual meeting in Mendoza and other more glacier-specific events such as the glaciology workshop planned for the event.
Dr. Carla Gulizia, recently incorporated as a new member of the ANDEX Scientific Committee, has various research activities and experiences in different initiatives of WMO and WCRP. These activities and experiences represent a valuable asset that would hopefully strengthen the interactions with these global institutions and their extended network of individuals in the different Andean countries and elsewhere.

AsiaPEX

Three members are contributing Global Precipitation Experiment (GPEX) as an SSG Member (Kyung-Ja Ha) and Working Group co-chairs (Akiyo Yatagai and Toru Terao). They participated in the first SSG meeting on 6-7 December 2024 in Washington DC. Possibility of AsiaPEX as an anchor project was discussed.
The 2nd Joint Workshop on the A3 Foresight Program: “Networking Climate Change Hubs for Promoting Future Earth over Northeast Asia” was held on 18-20 Dec. 2023 and was summarized in Yuan et al. (2024). Participants from South Korea, Japan and China shared and discussed their recent research progresses in the area of climate change, monsoon, extreme events, climate–aerosol interactions, climate projections, and climate impacts over Northeast Asia.

Central Asia Initiative

The activity has increased our coordination with CARIN; (Central Asia Research Information Network) While in Sapporo we connected with START office in China, we have collaborated with START in earlier efforts.
Maksim Kulikov: participated in two COP29 side events, organized by ADBI:

- Roundtable discussion (Khazar University): "Youth and Community-Led Climate Solution for the Resilience" - no particular presentation, just talking and sharing opinions
- Presentation at AzTU: "Impact of Climate on Natural Resources in the Naryn and Batken provinces of Kyrgyzstan, Comparing Two Regions"
- online presentation at COP29 Kazakhstan pavilion: "MSRI research projects"

INARCH

INARCH 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) (https://water-future.org/working_groups/climate-impacts-on-global-mountain-water-security/). Also, INARCH contributes to UNESCO Intergovernmental Hydrological Programme 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 members are now co-chairholders of the UNESCO Chair in Mountain Water Sustainability: https://research.ucalgary.ca/unesco-chair-mountain-water-sustainability. INARCH 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 to show leadership and provide guidance for governments to implement this. The Global Water Futures (GWF; www.globalwaterfutures.ca) 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 strongly links with the mountain research components of GWF and GWFO. Distinguished Professor John Pomeroy leads and directs INARCH, GWF and GWFO. A resolution (https://digitallibrary.un.org/record/3994297?ln=en) was passed by the

UN General Assembly in December, 2022, which noted “shrinking of the cryosphere, with mass loss from ice sheets and glaciers and reductions in snow cover, which have decreased the stability of high mountain areas and change the amount and seasonality of runoff and water resources in snow-dominated and glacier-fed river basins” and declared 2025 as the International Year for Glaciers’ Preservation and each March 21st as the World Day for Glaciers. The UN-invited “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”. INARCH is well-positioned to support this initiative and contribute to its scientific milestones on snow and ice observations systems, assessment and prediction of their contributions to freshwater supplies, and development of modeling and information systems for mountain basins and development of adaptations in downstream river basins. It can also contribute to sharing knowledge and building scientific capacity. The results of COPE will be available for release in 2025 and will be a contribution to this year.

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 cross-cutting project are being further developed.

GRDC

- CLiC - Maintaining the Arctic Runoff Database (ARDB) as a subset of the GRDC database in support of CLiC.
- Arctic-HYCOS - Maintaining the Arctic-HYCOS quality assured river discharge dataset.
- UNESCO IHP FRIEND-Water – Integration of river discharge database from various FRIENDWater Programmes into the GRDC database. Negotiations to incorporate river discharge databases from FRIEND-Water Programmes are 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, 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 HydroSOS activities with data and technical expertise.
- Support WMO WHOS (WMO Hydrological Observing System) activities.
- Support and provide basis for WMO State of Global Water resources Report 2023.

GPCC

GPCC is part of the Global Terrestrial Network Hydrology (GTN-H).

Workshops and Meetings

List of Workshops and Meetings Held in 2024

GWF

GWF Observatories (GWFO) Launch Event, April 17, 2024: GWFO is a follow-on project, emerging from and strongly linked to GWF (https://gwfo.ca/), and its partner institutions. GWF hosted a nationwide launch and celebration of GWFO (https://gwf.usask.ca/events/2024/04/gwfo-launch.php) at the University of Saskatchewan (USask) with simultaneous in-person events at the University of Waterloo and the University of Windsor. The Launch was also live-streamed online via Zoom. It included an overview of the program, remarks from users/partners including the Parliamentary Secretary and

Special Advisory on Water to the Prime Minister, and brief summaries from each of the main GWFO partner institutions, as well as a showcase of some of the sensors and deployable systems. There were over 260 individuals who attended online or in person from over 50 different organizations and six countries. The Launch generated significant media coverage and a press conference at USask, leading to many news articles (see https://gwfo.ca/resources/media-reports.php), and subsequent follow-up from interested potential partners and data users. The Launch event can be viewed at: https://youtu.be/uX89uuGhPqM.

GWFO Workshop on Observations and Data (October 23 & 24, 2024): GWFO held an online workshop to bring together the GWFO facility leads and managers and the GWFO staff to better understand our observations and data systems. This was primarily aimed at updating ourselves and exploring improved and best practices to be fully prepared for the CFI Standing Advisory Committee review in December. This was a very worthwhile and productive meeting to see the full scope of GWFO and to discuss how to move forward. More information, including a brief summary of the discussions and outcomes, and recordings of the Zoom presentations and discussions are found here https://gwfo.ca/news-events/events.php.

Baltic Earth

- European Geophysical Union General Assembly, Vienna, 15-19 April 2024: Session on Interdisciplinary approaches to understanding processes in coastal regions and nature-based solutions Convener: Maren Voss, co-conveners: Marcus Reckermann, Timothy Stojanovic, Eleonora Gioia, Fereidoun Rezanezhad, Sara E. Anthony, Eva Ehrnsten https://meetingorganizer.copernicus.org/EGU24/session/50355
- 5th Baltic Earth Conference New Challenges for Baltic Sea Earth System Research, Jurmala, 13-17 May 2024 with Young Scientist event at Jurmala *https://baltic.earth/jurmala2024*
- 2nd Baltic Earth Workshop on Multiple Drivers of Earth system changes in the Baltic Sea region, Helsinki, 4-5 Dec 2024 *https://baltic.earth/multipledrivers2024*
- 5th EN Clime meeting 5 March 2024
- 6th EN CLIME meeting 3 Dezember 2024
- 20th BESSG meeting online 13 Feb 2024
- 21st BESSG meeting, Jurmala, 12 May 2024
- 22nd BESSG meeting, online, 10 Dec 2024
- GHP Meeting online 3 July 2024
- Baltic Earth Scientific Online Colloquium: Total of 6 presentations
- Presentation on Baltic Earth by MR, Deutsche Meteorologische Gesellschaft, Hamburg, Germany, 17 Sep 2024
- Presentation on Baltic Earth by MR, International Seminar of Institute of Coastal Research, Hereon, Geesthacht, Germany, 21 Nov 2024

TPE-WS

- The session of “The Third Pole Environment (TPE) under global changes” have been organized in the European Geosciences Union 2024 on 15th - 20th April 2024 in Vienna, Austria. 30 oral presentation and 23 Posters have been shared during the meetings.
- The 9th GEWEX Open Science Conference has been held in Sapporo, Japan during July7-12.
- 2024 Annual INARCH (International Network for Alpine Research Catchment Hydrology) Workshop, Lanzhou and Zhangye, China, October 14-18, 2024.

ANDEX

The ANDEX Annual Meeting was held in Lima, Peru, May 26-29, 2024. During this event, the progress of the ANDEX Scientific and Implementation Plan until 2032 was presented. In addition, three parallel events were held for the first time: Hydro glaciology in Huaraz, Physics of the Atmosphere in Huancayo and Interdisciplinary and Transdisciplinary in Cuzco. In the context of this session, an exclusive event was organized for JovenANDEX, which consisted of the presentation of scientific posters on the most relevant articles for the Andean region. Quarterly virtual meetings were also held with the members of the ANDEX Scientific Committee, in order to evaluate the periodic work topics, as well as to present advances, news and programmed activities. As mentioned above, on December 7-8, 2024, we participated in the AccelNet-ACCORD 1st Annual Meeting in Washington DC, USA. This recently approved "Network of network" project is aimed at bringing together and facilitating the cooperation and interaction of the existing research projects working on Andean hydroclimate and related issues. The project will be funded by NSF until 2028 and offers a great opportunity for enhancing many of the ANDEX activities in collaboration with other colleagues and research programs from the region. The meeting included and overview of the AccelNet-ACCORD project by the PI Dr. Mathias Vuille, and presentations of the following programs: ANDEX (Mariano Masiokas – via Zoom), CliC (Ray Bradley, Keith Alverson), UNESCO-IHP (Anil Mishra), MRI and GEOMountains (James Thornton), IAI (Omar López), GTNH (Andrés Rivera - via Zoom), DaR (Jeremy Ely - via Zoom, and Wouter Buytaert), ACCION (Mathias Vuille, & Andres Rivera - via Zoom), SAAG (Kristen Rasmussen & María Laura Bettolli), GLACIOCLIM (Antoine Rabatel), ANDES-C2H (Thomas Condom), and TARN (Jeff McKenzie & Bryan Mark).

H2US

- AMS Annual Meeting, January 2024, Baltimore, MD
- AGU Water Science Conference, June 2024, St. Paul MN
- GEWEX GHP & OSC, July 2024, Sapporo Japan
- 2024 NASA Community Snow Meeting, August 2024, Boulder, Colorado
- 1st Children's Health and Climate Change Symposium, November 2024

AsiaPEX

- 1st Workshop on Projection and Mitigation of Mega-Geo-Disasters under Changing Climate,
- 14-15 Mar 2025, Kathmandu, Nepal.
- Workshop on AsiaPEX in Southeast Asia and Mongolia, 8 / 12 Jul 2024, Keio Plaza Hotel /
- TKP Sapporo White Building Conference Center, Sapporo, Japan
- GEWEX/OSC AsiaPEX Session and Workshops, 9 Jul 2024, Keio Plaza Hotel, Sapporo, Japan.
- Core-to-Core AsiaPEX Reception, 11 Jul 2024, TKP Sapporo White Building Conference
- Center, Sapporo, Japan.
- Workshop on Storm Modeling over NE Indian Subcontinent, 12 Jul. 2024, TKP Sapporo White Building Conference Center, Sapporo, Japan

Central Asia Initiative

Proposed Central Asia Regional Hydroclimate Project: Workshop on Climate Change: Better Data, Modeling & Planning for Climate Adaptation in Central Asia. Osh State University, Osh, Kyrgyzstan, April 29–May 1, 2024

INARCH

INARCH Workshop, Lanzhou and Zhangye, China, October 14–18, 2024, https://inarch.usask.ca/news-events/inarch-workshop-2024.php

TEAMx

- An Online Community Meeting was held on 19 January 2024. The meeting served to update everyone interested in TEAMx on the latest developments. Furthermore, it provided a platform for new members to present project ideas.
- At the EMS Annual Meeting in Barcelona (2 – 6 September 2024), a session on "Transport and Exchange Processes in the Atmosphere over Mountains" was convened by members of the TEAMx community.
- The 4th TEAMx Workshop took place as a hybrid event in Innsbruck on 19 – 20 November 2024. The Workshop focused on providing information about ongoing and planned TEAMx activities, collecting input on the Implementation Plan from the TEAMx community, and presenting ongoing and planned TEAMx research activities.

RivEx

- Monthly meetings (leading team)
- 9th GEWEX Open Science Conference, June 2024, Sapporo, Japan
- Fifth Space for Hydrology Workshop, GEWEX Hydrospace, December 2023, Lisbon, Portugal
- SWOT Science Team Meeting, June 2024, Chapel Hill, NC, USA
- 30 years of progress in radar altimetry symposium, EUMETSAT, September 2024, Montpellier, France
- AGU Annual Meeting, December 2024, Washington, DC, USA

Floods

- The Floods team organized a session at the 9th GEWEX OSC in Japan
- An in-person meeting was held during the GEWEX OSC
- An in-person meeting was held in the AGU to discuss the plan of action and the focus and objectives of Floods CC proposal

PannEx

- FAIRNESS Workshop on Exploitation of Mapping, Modeling, and Micrometeorological Data- Based Applications, 5-6 September 2024, Barcelona, Spain
- Related Sessions at the EMS Annual Meeting, 2-6 September 2024, Barcelona, Spain (e.g. OSA2.2 session on Agricultural and Forest Meteorology, UP2.2 session on Exploring the interfaces between meteorology and hydrology)
- Training school on micrometeorological measurements and applications (in the framework of COST Action FAIRNESS) and the 7th PannEX Meeting, 10-15 June 2024, Budapest, Hungary
- General meeting of FAIRNESS, 23-24 April 2024, Vienna, Austria (BOKU)
- Hosting GEWEX SSG-36, 22-26 April 2024, Budapest, Hungary (HungaroMet national meteorological service)
- 2nd ISDTA & DIGITAGRA, 1-4 October 2024, Osijek, Croatia
- International conference on air and water components of the environment, 22-23 March 2024, Cluj-Napoca, Romania

GGN

- First Workshop at GEWEX Conference in Sapporo (~25 attendees)
- Splinter meeting at the IAH World Groundwater Congress in Davos (~10 attendees)

GRDC

- 15th Steering Committee Meeting for GRDC, 26.06.2024, online

GPCC

- EGU General Assembly, 14-19 April 2024, Vienna, Austria
- GTN-H Meeting, 5-6 June 2024, Geneva, Switzerland
- GHP Meeting, 3-5 July 2024, Sapporo, Japan
- GDAP Meeting, 6 July 2024, Sapporo, Japan
- WMO Workshop "State of the Climate Modernization", 9-11 July 2024, Offenbach, Germany
- EMS Annual Meeting, 2-6 September 2024, Barcelona, Spain
- WMO Workshop "Preparation for the State of the Climate Report of Arab Region", 21- 22 November 2024, online

List of Workshops and Meetings Planned in 2025 and 2026

GWF

GWF will host a GWF synthesis session at the joint Canadian Meteorological and Oceanographic Society (CMOS) 59th Congress and the Canadian Geophysical Union (CGU) Annual Meeting in Saskatoon, SK, Canada, 25-29 May 2025.

Baltic Earth

- Baltic Earth Online Colloquium Series cont. https://baltic.earth/colloquiums
- Baltic Sea Science Congress in Sopot, Poland, 26-30 May 2025 https://www.bssc2025.pl/
- Baltic Earth session @ EGU2025 Vienna, 27 April – 2 May 2025 Coastal dynamics and processes under changing climate and changing human activities Laurent Amoudry, Kaja Gentsch, Markus Meier, Maren Voss https://meetingorganizer.copernicus.org/EGU25/session/52605
- Baltic Earth Winter School in Klaipeda, Lithuania, 24 – 28 March 2025 https://baltic.earth/events/115039/index.php.en
- Baltic Earth Summer School on Askö, Sweden, 18-25 August 2025 Website in preparation
- Baltic Earth Master Course, Winter Semester 2024/2025 https://baltic.earth/news/115042/index.php.en

TPE-WS

- European Geosciences Union, April 27- May 2, 2025, Vienna, Austria
- Asia Oceania Geosciences Society, July-August 2025, Singapore
- European Geosciences Union, April - May 2026, Vienna, Austria
- Asia Oceania Geosciences Society, July-August 2026.

ANDEX

The ANDEX Annual Meeting will be held in Mendoza, Argentina, October 12-18, 2025. This event will bring together members of the Scientific Committee, as well as project leaders and collaborators. Among its main objectives are the presentation of the progress of the ANDEX Scientific and Implementation Plan towards 2033, already approved by GEWEX, and the deepening of the consolidation process of its scientific-academic network, as well as the strengthening of links with strategic actors. As in Lima, Peru, at least three workshops will be held in different locations in Argentina, focusing on the following topics: i) Hydro glaciology, ii) Physics of the Atmosphere, and iii) Interdisciplinarity and climate change in the Andes. For the organization of these events, we are coordinating collaborations and funding with various international agencies and institutions, such as IAI and MRI, among others.

The glaciology course in Mendoza in 2025 was recently discussed at the end of the 1st AccelNet-ACCORD meeting in Washington (see above) as one of the activities that will be supported through that program.

H2US

- AMS Annual Meeting (technical session), January 2025, New Orleans, LA
- AWRA (presentation), April 2025, Anchorage, AK, (travel support may be needed)
- GHP Meeting, June 2025, Montreal, (travel support may be needed)

AsiaPEX

- AOGS2025, HS-04, The Third Pole Environment and High Mountains of Central Asia - Hydrometeorological Processes and Human Dimension. 27, Jul 2025-1, Aug 2025. Sands
- Expo & Convention Centre, Singapore.
- JpGU2025, A-CG45, AsiaPEX field campaign strategies for changing Asian monsoon
- precipitation. 26 May 2025, Makuhari MESSE, Chiba, Japan.
- 1st International Biennial Conference of the Asian Association for Environmental History (AAEH 2025), several panels, Takamatsu, Japan.
- IAEG-Asian Regional Conference 2025, 27-29, Nov. 2025, Kathmandu, Nepal.

Central Asia Initiative

- Summer School: 4th workshop on Central Asia proposed RHP, mid-September 2025. To be held in Central Asia, specific location to be determined. Main topics will be use of downscaled data and/or hydrologic modeling
- International Mountain Conference 2025, September 14-18, 2025, Innsbruck, Austria. Session title: Precipitation Changes in Mountainous Hydroclimates; (Brody convenor); https://imc2025.info/imc25/sessions-n-workshops/focus-session/fs-3-165-mountain-precipitation-change/

INARCH

- EGU General Assembly 2025 – INARCH session on “Improving Measurement, Understanding, and Prediction of the Mountain Cryosphere and Hydrological Cycle through Alpine Research Catchments”
- INARCH Workshop Obergurgl, Austria, September 11–13, 2025, and
- International Mountain Conference 2025, Innsbruck, Austria, September 14–18, 2025

TEAMx

- Two TEAMx related sessions have been proposed for the International Mountain Conference in Innsbruck (14 – 18 September 2025): (i) Do we need more atmospheric data in mountainous terrain? – the TEAMx field campaign and what we can learn from it and (ii) High-Resolution Modeling of the Atmosphere
- The TEAMx CIG will approach the organizers of the International Conference on Alpine Meteorology (ICAM; 19 September – 3 October 2025, Croatia) to propose a TEAMx session
- Based on a suggestion from the Science Advisory Board an online meeting of TEAMx PIs will take place in spring 2025 after the winter EOP to discuss lessons learned prior to the summer EOP
- With TEAMx activities focusing on the TOC in 2025, a 5th TEAMx workshop is foreseen for 2026, focusing on presentations of first results from the TOC

RivEx

- AGU Annual Meeting 2025, December 2025, USA
- GEWEX Hydroclimatology Panel (GHP) meeting, July 2025, Montreal, Canada

PannEx

- International conference on air and water components of the environment, 21-23 March 2025, Cluj-Napoca, Romania

GGN

- Splinter meeting at General Assembly EGU
- GGN meeting at Sustec, China
- Splinter meeting at AGU

GRDC

- WMO Technical Meeting for State of the Global Water Resources Report 2024,
- Geneva, Switzerland
- Living Planet Symposium, 23-27 June 2025, Vienna, Austria
- GHP, 9-11 July 2025, Montreal
- IAHS Scientific Assembly, 5-10 October 2025, Roorkee

GPCC

- EGU General Assembly, 27 April–2 May 2025, Vienna, Austria
- GDAP Meeting, 19-23 May 2025, Paris, France
- GHP Meeting, 9-11 July 2025, Montreal, Canada
- EMS Annual Meeting, 8-12 September, Ljubljana, Slovenia

Other Meetings Attended On Behalf of GEWEX or Panel in 2024

GWF

John Pomeroy, Director of GWF, was asked to give three keynote talks and contribute discussion on two panels at COP29 in Baku in November for sessions organized by UNESCO, WMO and Tajikistan. Topics include the international year for glaciers preservation, UN decade of action on the cryospheric sciences, UNESCO water sciences report and contributions of the UNESCO Intergovernmental Hydrological Programme. This was to inform the international research agenda and address the risk of loss of snow, ice and hydrological stability to society to the COP deliberations, and the adaptations and solutions that GWF can contribute to.

AsiaPEX

GPEX U.S. Agencies workshop and SSG meeting, 6-7 Dec. 2024, Washington DC, USA.

INARCH

John Pomeroy, Chair of INARCH, was asked to give three keynote talks and contribute discussion on two panels at COP29 in Baku in November for sessions organized by UNESCO, WMO and Tajikistan. Topics include the international year for glacier preservation, UN decade of action on the cryospheric sciences, UNESCO water sciences report and contributions of the UNESCO Intergovernmental Hydrological Programme. This was to inform the international research agenda and address the risk of loss of snow, ice and hydrological stability to society to the COP deliberations, and the adaptations and solutions that INARCH can contribute to

PannEx

- 9th GEWEX Open Science Conference, 7-12 July 2024, Sapporo, Japan. GEWEX GHP meeting, 3-5 July 2024, University of Hokkaido, Japan

GGN

- International Association of Hydrogeologists (IAH)

GRDC

- WMO Technical Meeting for State of the Global Water Resources Report 2023, Geneva, Switzerland
- EGU 2024, GRDC-Caravan: extending the original dataset with data from the Global Runoff Data Centre, Vienna, Austria
- 5th Baltic Earth conference: The BALTEX Hydrological dataset of GRDC, Jurmala, Latvia
- 11th GTN-H Panel Meeting, Geneva, Switzerland
- 2024 GHP Meeting, Sapporo, Japan
- 9th GEWEX OSC, Sapporo, Japan
- Copernicus In-situ Hydrology Workshop, EEA, online
- 17th DWD Klimatagung, DWD, Offenbach, Germany
- 25th TOPC Meeting, GCOS, Rome, Italy

Publications during Reporting Period

List of Key Publications

See the detailed list of publications in each activity report.

2.3.1 GHP Rapporteurs Report

Panel: GEWEX Hydroclimatology Panel (GHP)
Rapporteur(s): Jason Evans, Camila Alvarez Garreton

Adherence to GEWEX and Panel's objective(s)

GEWEX's goals:

Goal 1. Determine the extent to which Earth's water cycle can be predicted. Related areas: reservoirs; flux exchanges; precipitation extremes.
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: i) Forcing-feedback understanding; ii) ABL process representation; iii) Understanding Circulation controls; iv) Land-atmosphere interactions.
Goal 3. Quantify anthropogenic influences on the water cycle and our ability to understand and predict changes to Earth's water cycle.

GHP's goals:

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 from an integrated perspective.

Adherence to GEWEX and Panel's objectives(s):

GHP includes 7 Regional Hydroclimate Projects (RHP), 6 Cross-Cutting themes (CC), 2 Global Data Centers, and 4 GHP networks. Some of these elements are approved and running, others are at earlier stages.

There are an impressive number of activities contributing to GHP. While there is variety within these activities, they adhere to the overall goal of GEWEX and GHP. In general, the activities in GHP also contributed towards the GEWEX goals.

Achievement of annual goals for this reporting period

GHP achieved a number of goals for 2024 including:

- Updating terms of reference and guidelines for various GHP elements.
- Revision and approval of the Scientific and Implementation Plan for the ANDEX RHP
- Revision and conditionally approving scientific proposal from AsiaPEX Science and River Experiment (RivEX) cross-cut theme, and the Global Groundwater Network (GGN)

Each GHP element also has a list of achievements for 2024 making for a long list of outcomes achieved in 2024. Major accomplishments and results in this reporting period of:

Regional Hydroclimate Projects (RHPs):
Global Water Futures

- Finishing various synthesis activities (e.g. GWF Briefing Book –Realizing Global Water Futures: a Summary of Progress in Delivering Solutions to Water Threats in an Era of Global Change)
- Transitioning to the Global Water Futures Observatories (GWFO), focusing on long-term observational data for water security.

Baltic Earth

- Planning next phase of Baltic Earth science including science plan and updated research topics.
- Ran a winter school, summer school and master course on Baltic Earth science
- Finalized a journal special issue “Assessing the Baltic Earth System” in Oceanologia

ANDEX

- Completion of science and implementation plan
- Expanded international collaborations
- Two review papers in atmospheric and hydrological modelling
- ListANDEX continues to be an important communication and dissemination channel between ANDEX members, JovenANDEX and the Scientific Committee.

AsiaPEX

- Data collected through a number of projects
- Seminars given within the South Asian meteorological Association (SAMA) Weekly Online Lecture Series

Central Asia Initiative

- Held RHP initiating workshop and distributed a summary report through GEWEX quarterly newsletter.
- Published an article outlining the case for the RHP
- The RHP core team has been created.

TPE-WS

- Maintenance of the “TPE Integrated Three-dimensional Observation and Research Platform”. The instruments of eddy covariance and radiation have been calibrated, and the data set of land-atmosphere interaction process have been collected.
- New instruments installed
- Publication of papers on the processes of land-atmospheric interaction processes. Fidings included that ET on the Tibetan Plateau exhibited a significant increasing trend – about twixe rate of global land ET trend.
- Taken the world’s longest ice core (324m) in the world’s mid to low latitude glaciers in Purog Kangri, Shuanghu county, Tibet. The ice core can help for study the climate and environment change over the past tens of thousands of years.

H2US

- Several project proposals for funding are at various stages the process.

Cross-cutting projects:

INARCH ((International Network for Alpine Research Catchment Hydrology))

- Completion of Common Observing Period Experiment (COPE), a globally unique initiative that collected critical high-mountain hydrometeorological data.
- COPE has finished the data collection phase and is moving into Analysis and modeling activities

TEAMx (Transport and Exchange Processes in the Atmosphere over Mountains Experiment)

- Completed the numerical modelling plan and data management plan
- Establishment of six working groups (Atmospheric Chemistry, Mountain Boundary Layer, Mountain Climate, Orographic Convection, Surface-Atmosphere Exchange, and Waves & Dynamics).
- Next steps include deploying field instrumentation, coordinating model intercomparison studies, and preparing flight plans for atmospheric measurements over complex terrain.

- dET: No 2024 annual report for this activity was submitted to the GHP. The d-ET team is reshaping the activity under the leadership of Li Jia (GEWEX SSG) and Bob Su (GHP).

Floods

- Discussions to determine the way forward for this initiative continue
- Organized a session at the 9th GEWEX Open Science Conference (OSC) and held an in-person meeting to discuss research priorities.
- MOUNTerrain: Still seeking an active leadership for the MOUNTerrain CC focused on precipitation over mountainous terrain.

RivEX

- Held monthly meetings of the co-leads and quarterly meetings with the community to identify the main goals of the project
- Wrote a workplan
- Had a proposal funded through NASA for improving hydrological models and observational datasets.

Global Data Centres

Global Precipitation Climatology Center (GPCC)

- Updated dataset
- Updated version of a homogenized precipitation data set for Europe,
- HOMPRA-Europe Version 2

Global Runoff Data Center (GRDC)

- Updated existing dataset
- Updated the BALTEX stations draining into the Baltic Sea

GHP Networks

PannEX

- PannEX meeting held in Budapest, along with a summer school on micrometeorology measurements

Global Groundwater Network (GGN)

- Developed the aims/plan documentation and officially commenced the network
- launched website and started mailing list

Arisen or noted science issues

- Data is being published and made available by multiple GHP elements (great to see!)
- How can observational uncertainties be included in the analysis?
- Can efforts like GWFs “Weaving Science: Stories of Research Engagement” help to inform stakeholder engagement activities in other elements of GHP?

Emerging Science

How to best (most appropriately) AI/ML methods to address GHP science questions?

Future plans

RHPs

Global Water Futures

- Global Water Futures Observatories (GWFO) are discussing next steps

ANDEX

- Initiating activities in the science and implementation plan

AsiaPEX

- An experimental real time event attribution system on northern Japan region is now developing

Central Asia Initiative

- Regional downscaling modeling is beginning with development of data sets for the simulations.

Cross-cutting projects

INARCH

- working towards a Special Issue of Hydrological Processes, “Improving measurement, understanding, and prediction of alpine cold regions hydrological processes and their sensitivities to global change”

TEAMx

- A series of funding proposals have been submitted and await decisions

Floods

- Discussions to determine the way forward for this initiative continue

Global Data Centers

Global Precipitation Climatology Center (GPCC)

- Has new project that aims to develop artificial intelligence (AI) based tools for automatic detection and correction of wrong precipitation values

GHP Networks

Global Groundwater Network (GGN)

- Aims to launch working groups on key challenges and recruit additional members

Recommendations to Panel

- Consider how learnings from one GHP element can be passed to others. Many projects address similar challenges—how can they better share methodologies and insights? Getting together and sharing progress at GHP meetings is one step but perhaps there are others that could facilitate this sharing…
- Africa seems under-represented in GHP activities. Consider ways to include African participants/perspectives in activities – or even a new RHP?
- A key challenge for GHP (as for any GEWEX panel) is effectively synthesizing and transferring the scientific learnings gained from its diverse groups, projects, and cross-cutting activities to advance its core objective. In the case of GHP, the goal is "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 from an integrated perspective." To bridge the gap between project-specific findings and broader GHP objectives, the panel could include in its report a synthesis process that explicitly integrates how individual project learnings contribute to answering GHP’s overarching scientific question. This integrative scientific summary should go beyond listing activities and focus on scientific synthesis. Some conceptual schemes could also work for doing this integrative scientific summary.
- Thinking of RHPs: could the mature RHPs write a reflection on “advice for prospective RHPs” that could be compiled and shared with prospective RHPs?

- Cross-cut activities were partly created to facilitate interactions between RHPs. Do you know which RHPs are contributing to each CC? It might be worth encouraging RHPs to engage with the CCs if they are not already. RHPs provide a framework for combining cross-cut activity outcomes together.
- The section "List contributions to the GEWEX Science Goals and plans to include these" could also include an integrated summary of the contributions from the different GHP groups.
- We see merit in your considering a Pan-GHP meeting and encourage you pursue that.
- d-ET cross-cut could look to include cross-panel involvement.
- Another way to improve cross panel communication may be to hold panel meetings together with another panel - meeting together for a day or so and independently for the rest of the time.

Considerations for SSG

As the number of projects increases, securing long-term funding remains a challenge.

Additional Remarks

- The expansion of RHPs, Cross-Cuts, and Data Networks reflects a strong and growing GHP.
- The GEWEX Open Science Conference 2024 played a key role in fostering discussions and initiating new collaborations.

2.4 Global Land/Atmosphere System Study Panel

Full Panel Name (Acronym) : Global Land/Atmosphere System Study Panel
Reporting Period : 01 January - 31 December 2024
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 : 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
*Patricia Lawston-Parker, 2022 – Present
^Xianhong Meng, 2019 – Present
Vimal Mishra, 2023 – Present
Nicholas Parazoo, 2024 – Present
^Joshua Roundy, 2016 – Present
*Joseph Santanello, 2011 – Present
Asaminew Teshome Game, 2023 – Present
*Volker Wulfmeyer, 2020 – Present
*Yijian Zeng, 2020 – Present
^Yunyan Zhang, 2021 – Present

** GLASS Project Lead*
^ GLASS Liason to relevant initiative

Panel Objectives, Goals and Accomplishments during Reporting Period

Overall Panel Objective(s)

a) Improved modeling of land-atmosphere interactions 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.
b) To develop novel ways to evaluate experiments to address the central question, “Does my model describe land-atmosphere interactions in the climate system sufficiently well?”

List of Panel Goals

- Leverage 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 parameterisations (including MOST), surface flux partitioning, as well as vegetation and soil processes

- Improve and develop cutting-edge metrics and methods to confront land model performance with a focus on diurnal cycles

List of 2 to 3 Key Results

- PLUMBER2: MIP results that are now published suggest that latent heat flux and net ecosystem exchange of CO2 are better predicted by land models than sensible heat flux, which at least conceptually would appear to have fewer physical processes controlling it. Land models that are implemented in Earth System Models also appear to perform notably better than stand-alone ecosystem (including demographic) models, at least in terms of the fluxes examined here.
- SoilWat: SP-MIP hydrological regime analysis results reported that individual LSMs responded very differently to changes of soil parameters and sometimes responded counter-intuitively due to complex interactions of infiltration, soil evaporation and plant transpiration.
- CLASP: Secondary circulations driven by km-scale spatially organized thermal heterogeneity can be detected and quantified (indirectly) via a network of 3+ Doppler Lidars as is already available at the SGP site and will be available in level 4 GLAFO sites. This enables a path forward to provide quantitative measurements of surface-driven circulations to then be used to evaluate and improve sub-grid coupling schemes. It also enables strong interaction between GABLS, GLAFO, SoilWat, and CLASP as well as more direct collaborations with GASS moving forward.

Other Science Highlights

- **PLUMBER2**: Flux towers seem to indicate that ground heat flux almost consistently lags incident and net radiation, but in LSM outputs it strongly leads radiation. Theory supports the former, also confirmed by findings of other flux field experiment reported in the literature.
- **SoilWat**: The paper “Hydro-pedotransfer functions: a roadmap for future development” points out that most of the PTF development process has focused on refining and advancing the regression methods, while fundamental more mechanistic aspects have remained largely unconsidered. Most soil systems are not represented in PTFs, which have been built mostly for agricultural soils in temperate climates.
- **SIF-MIP** - The global sensitivity experiments, using coupled carbon-water cycle data assimilation and factorial simulations driven by climate and CO2, show the impact of anthropogenic forcing on the water budget at grid to global scale. The analysis shows impacts to water storage, as well as vertical and lateral flux terms including evaporation, transpiration, sublimation, and runoff (surface and subsurface).

Panel Activities during Reporting Period

List of Panel Activities and Main Result

GABLS

- Initial simulations carried out in two different mesoscale / large-eddy models.
- Plans and results from prototype simulations were presented at the GEWEX OSC meeting.

Irrigation cross-cut

- Members led an issue in the Agricultural Water Management on “Irrigation monitoring through Earth Observation (EO) data”.
- Collaborating on plans for the Central Asia Regional Hydroclimate Project in development.

LoCo

- NASA Advanced Information Systems Technology (AIST) proposal focused on data science and novel methods to integrate ground, suborbital and spaceborne nodes of PBL observation

- WH2yMSIE Field Campaign (Oct-Nov 2024) led by NASA-NOAA, focused on airborne combination of PBL related instruments. D) ARM-SGP working towards PBL height 'best estimate' combined product.
- New members/ambassadors: Eunkyo Seo (Asia) and Lisa Jach (Europe)

PLUMBER2

- First PLUMBER2 paper has been published: https://bg.copernicus.org/articles/21/5517/2024/
- Analysis of the conditions (in meteorological space) when LSMs are most reliably outperformed by ML is showing some interesting results
- Flux towers seem to indicate that ground heat flux almost consistently lags incident and net radiation, but in LSM outputs it strongly leads radiation. Theory supports the former, also confirmed by findings of other flux field experiment reported in the literature

SoilWat

- SP-MIP hydrological regime analysis results reported that individual LSMs responded very differently to changes of soil hydraulic parameters and sometimes responded counter-intuitively due to complex interactions of infiltration, soil evaporation and plant transpiration.
- The manuscript for 'Soil carbon potential' working group has been drafted. The main aim is to understand how much carbon sequestration potential is there globally.
- The paper "Hydro-pedotransfer functions: a roadmap for future development" points out that most of the PTF development process has focused on refining and advancing the *regression methods* between basic soil or environmental parameters and the parameters in the equations governing soil processes, while fundamental more mechanistic aspects have remained largely unconsidered
- The work on "Monitoring and Modeling the Soil-Plant System Towards Understanding Soil Health" underpins the importance of vital ecosystem functions for achieving sustainable development goals, yet its monitoring and modeling remain fragmented, limiting our ability to predict and mitigate the impacts of climate change and human activities.

CLASP

- Virtual seminar series focused on expanding CLASP to the global community
- Interactions with the MOSAI project in France. Members of the CLASP project have interacted and attended MOSAI workshops. MOSAI team members presented to the CLASP group in November.
- Members of the team have received new CLASP-related funding including developing metrics to evaluate space-time patterns of LST in the land surface models and observe the existence of thermally-driven secondary circulations over the new ARM AMF3-BNF site in northern Alabama in the United States.
- In collaboration with the LoCo and GLAFO projects, collaborations with NASA are beginning to participate in their efforts to better measure the PBL.

SIF-MIP

- Met several times with modelers to discuss protocol and modeling activities.
- Parazoo attended several meetings in 2024 to discuss SIF MIP activities.

GLAFO

- A document is in preparation to define a GLAFO site and to establish international agreements about duties and responsibility as well as data formats. It is envisioned to use obs4MIP in accordance with the plans of ESMO. It is planned that SIRTA in France is also joining the GLAFO network and that the ARM SPG site contributes by making their data in this format available, too.

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

PLUMBER2

- Working with Fluxnet folk to automate delivery of flux tower data, with LSM-focused QC, in ALMA netCDF format, to modelevaluation.org. API is mostly now complete.
- Funding secured from two national research infrastructure projects (ACCESS-NRI, climate modelling support to develop modelevaluation.org

SoilWat

- Upcoming ISMC-GEWEX workshop (14-16 July, Reading, UK) aims to identify and address research gaps in the modelling of soil processes in LSM. The main objective is to write a paper that will outline a roadmap, identifying the next frontiers and challenges.

CLASP

- Ongoing efforts are writing up a perspective/review paper that summarizes the efforts of CLASP over the past five years and provides a lessons learned perspective to provide context on the future directions of heterogeneous coupling in coupled land-atmopshere models.

SIF-MIP

- Looking for volunteers to lead the main tower-based model intercomparison effort. SIF-MIP modelers Haoran Lu (U Wisconsin) and Rong Li (U Virginia) are the main candidates to act as lead and co-lead, respectively.

GLAFO-GABLS-LoCo-CLASP

- The new emerging GABLS project aims to more formally intertwine GLAFO, LoCo, and CLASP to explore how heterogeneity impacts the boundary layer development and how GLAFO-like observations can represent the processes.

ML4LM

- Webinar series (monthly, first webinar on 20 January) throughout 2025 to jump start the project and bring together the global community working on the use of machine learning in land modelling.

LAFI

- It is proposed that the Collaborative Research Unit 5649 “Land-Atmosphere Feedback Initiative (LAFI)” funded by the German Research Foundation (DFG) become a GLASS project and joins forces with CLASP and MOSAI as an international network of key projects on L-A feedback.

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

- Starting to devise spin-off projects from CLASP including a MIP of LST space-time patterns and revisiting turbulence parameterizations. The turbulence effort will be primarily led by incoming GLASS panel member Marc Calaf.
- Looking to reinvigorate urban land-atmosphere interactions efforts within GLASS (e.g., Urban PLUMBER, also via appointment of a new GLASS member).
- Started planning for a Pan-GLASS meeting to be held tentatively in 2027. This workshop aims to galvanize the global GLASS community.
- The SoilWat “Soil-Cloud Cascade” sub-project (lead Zeng) that was initiated with Yunyan Zhang, requires some new momentum.
- The 5-year AFESP (Advancing the Frontiers of Earth System Prediction) VaaSS project (lead Verhoef) that sits under SoilWat kicked off in October 2024. VaaSS (‘Vegetation as a Soil Sensor’) will contribute towards a high-fidelity ECMWF Integrated Forecasting System via ground-breaking and ambitious data-assimilation of the dynamic soil-vegetation hydraulic continuum

- We will discuss key scientific objectives such as
- the replacement of Monin-Obukhov Similarity Theory (MOST) by advanced and more accurate theories on flux-driving variable relationships
- Advanced understanding of evapotranspiration
- Investigation of the role of land surface heterogeneity on L-A feedback and upscaling of surface fluxes
- Investigation of entrainment as key driver of L-A interaction in the convective boundary layer

Science Issues and Collaboration during Reporting Period

Contributions to Developing GEWEX Science and the GEWEX Imperatives.

a. Data Sets

SIF-MIP

- Curated tower flux and met data and SIF data with collaborators from the University of Utah and Jet Propulsion Laboratory

LoCo

- New DOE-ARM PBL height VAP dataset (Damao Zhang and Yunyan et al.) under development.
- Global PBl height characterization dataset from wind profiler network (Salmun et al.).

Irrigation

- Satellite-derived Irrigation Water Use (IWU) data sets over the Ebro basin (Spain), Po valley (Italy), and the Murray-Darling basin (Australia) available at: https://zenodo.org/records/7341284. The products are an output of the ESA Irrigation+ project.
- Long-term IWU data set developed by leveraging satellite data within the ESA CCI-AWU data sets to be delivered soon. Targeted areas: CONUS, India, Murray-Darling basin, Ebro basin.

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 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 and unstable PBL, high-resolution satellite observations of surface and vegetation variables, UAV observations of land surface, and in the future also isotope measurements and fiber-optical distributed sensors.

CLASP

- Datasets of summarized space-time behavior of land surface temperature over the Contiguous United States (GOES 16/17) and global (Copernicus LST). These data derived from km-scale LST hourly data provide insights into the diurnal cycle of thermal spatial patterns. This data is then being explored in the context of evaluating land surface models to revisit how these models represent thermal heterogeneity.

b. Analysis

PLUMBER2

- Abramowitz, G., et al., 2024: Results suggest that latent heat flux and net ecosystem exchange of CO2 are better predicted by land models than sensible heat flux, which at least conceptually would appear to have fewer physical processes controlling it. Land models that are implemented

in Earth System Models also appear to perform notably better than stand-alone ecosystem (including demographic) models, at least in terms of the fluxes examined here.

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 NetCDF such as obs4MIP.

SoilWat

- The AFESP VaaSS project will actively engage with the latest theory and modelling of the soil-plant hydraulic and thermal system, to work towards an unified 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 to improve simulation of the water-, energy-, and carbon balance.

CLASP

- Building on the derived space-time data from the LST global data, analysis of a model ensemble is being explored to understand how meteorology and structural uncertainties inform the simulated diurnal LST space-time patterns. This analysis is highlighting the poor performance of contemporary models to simulate realistic space-time patterns of surface temperature. It also presents an opportunity to potentially explore a model intercomparison to understand the performance of space-time patterns of LST across global land surface models. The work to evaluate model performance of space-time patterns of LST in the GFDL was recently funded by NOAA.
- The project is looking to provide stronger measurement-based evidence for the results that have emerged from the LES experiments. Ongoing analysis is leveraging the available Doppler Lidars over the Southern Great Plains site (SGP) in Oklahoma and the LST data from GOES 16/17 to understand if the early day thermal setup has an influence in the emergence of dispersive kinetic energy in the afternoon.

c. <u>Processes</u>

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, and morning transition and afternoon decay

SoilWat

- There is a discussion on how soil properties (and 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 (via different PTF parameters) will impact the evaporative fraction that is closely linked to shallow cumuli. It is to note 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).

CLASP

- One of the themes that has emerged from the CLASP project is the understanding that heterogeneity over the land surface can have profound impact on the mesoscale atmospheric response but also on the local surface fluxes. This has led to efforts to think about revisiting surface fluxes with the goal in mind to harness the heterogeneity information to establish a more

proper coupling. This will require a revisiting of how we think of the process of turbulent surface fluxes and go back to the drawing board for land-atmosphere coupling.

d. Modeling

GLAFO

- Modeling will be performed in connection with LAFI and GABLS. Particular focus will be placed on: Simulation of the land-atmosphere system from meso- down to turbulence-permitting scales to study scale interaction, scaling laws, and revisit turbulence parameterizations (e.g., Monin Obukhov Similarity Theory) as well as the effect of micro-scale flow on surface and PBL properties. There will be a combination with single-column models and LES with homogeneous surface, and a focus towards mostly multi-nested design under realistic large-scale forcing including data assimilation.

SoilWat

- STEMMUS-SCOPE model runs for PLUMBER2 sites have completed. It turns out that the modelevaluation.org is not only applicable for evaluating LSM performance, but the other way around, the LSM model can help identify bugs in the meta data of driving force (e.g., the canopy height and reference height of different sites).

CLASP

- New funding for CLASP will focus on setting up LES experiments over the new AMF3-BNF site in northern Alabama. This work aims to better understand surface thermal heterogeneity driven secondary circulations. These experiments will be compared to the available Doppler Lidars at the AMF3-BNF site which is already mostly suitable as a GLAFO site. This work will complement efforts of the new GABLS as well as the efforts in SoilWat and GLAFO.

e. Application

GLAFO

- New parameterizations of surface fluxes, ABL turbulence, and stomatal resistance for crops
- NWP for nowcasting
- NWP from short- to medium-range
- Sub-seasonal to seasonal simulations
- Advanced km-scale regional climate projections by incorporation of better representation of L-A feedback and vegetation properties

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.

f. Technology Transfer

GLAFO

- Commercialization of remote sensing systems: The first commercial and operational water-vapor and temperature Raman lidar is now operated at MOL-RAO in Lindenberg
- Operational turbulence-permitting forecasting
- Operation of advanced instrumentation at other GLAFOs

SoilWat

- Soil process knowledge transfer from soil to land surface community, and further to understand land-atmosphere interactions. The potential cross-cut group 'Soil-Cloud Cascade' has a great

potential contributing to the technology transfer here from soil community to atmosphere community and vice versa.

g. Capacity Building

GLAFO

- Summer and Spring schools for students at LAFO
- Incorporation of GLAFO science in educational BSc and MSc programs
- Collaboration with forecast centers
- Collaboration with developing countries such as Ethiopia
- Educational efforts planned at all sites to demonstrate the measurement methodology, operation, maintenance and processing of GLAFO data, also in Peru

SoilWat

- Co-organize WG meetings with ISMC Soil Thermal Properties WG, Pedotransfer Function WG, Soil Carbon WG, Soil Math WG for bridging soil processes and Earth system models.
- AGU session "Advances and Challenges in Soil and Critical Zone Science"

CLASP

- Over the past few years, many PhD students and postdoctoral research associates have been funded through CLASP and associated projects.
- Interaction with the MOSAI project in France that is a "cousin" project to CLASP. These interactions will continue in the coming year with possibilities of joint projects emerging down the road.
- Collaboration with climate modeling centers in their development and evaluation of sub-grid coupling parameterizations.

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?

SIF-MIP - The ongoing data assimilation experiments will evaluate impacts of SIF and other joint vegetation, carbon and water constraints on the water pools including plant available and unavailable water in soils. These experiments range in scale from a few towers in high latitude and high-altitude environments, to global and long term.

LoCo - Inherently, the LoCo paradigm describes the connections between reservoirs (SM), fluxes (ET), the PBL, and ultimately clouds and precipitation (extremes). As such Earth's water cycle consists 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.

Irrigation - 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.

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?

SIF-MIP - The ongoing data assimilation experiments will evaluate impacts of SIF and other joint vegetation, carbon and water constraints on the water fluxes including evapotranspiration and runoff. These experiments will focus on a few towers in high latitude and high-altitude environments.

LoCo - 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 satellites, but surface fluxes and PBL processes remain a significant challenge in routinely monitoring them.

Irrigation Crosscut The irrigation effort 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.

GLAFO - Studies are already ongoing with GLAFO surface energy balance measurements and in collaboration with the new GABLS to gain a better understanding of both surface fluxes but more importantly the vertical profile of fluxes and how these changes in time (and space).

CLASP - The sensitivity of LST space-time patterns to turbulence parameterizations highlights the critical role that turbulent surface fluxes play in the space-time organization of thermal heterogeneity and thus the micro to mesoscale coupling between the land surface and atmosphere. The sub-diurnal modeling of surface fluxes is deficient and needs to be addressed for the purposes of modeling cumulus clouds and convection in numerical weather prediction and climate models.

SoilWat - The project is evaluating how parameterization of PTF/Soil Properties will impact the water, energy, and carbon cycle (at multiple spatiotemporal scales). Ultimately, this will improve predictions of land surface states and fluxes.

3. Precipitation Extremes*:*

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

LoCo - 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.

GLAFO - Although there is no expected direct contribution here, the data collected at the GLAFO sites will provide information on the pre-convective environment and its relation to convection initiation.

CLASP - Representation of km-scale thermal 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. This brings to light the need to think much more carefully how thermal heterogeneity over the land surface is accounted for in the coupling with the atmosphere.

SoilWat - The improved description of soil processes in Earth system 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.

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?

SIF-MIP - The planned data assimilation experiments will evaluate impacts of different observational constraints on energy, water, and carbon exchanges. Data assimilation systems will look for a solution which 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.

GLAFO - To be studied with GLAFO long-term measurements. These will contribute to the understanding of the L-A feedback chains over the 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.

SoilWat - 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: coupled soil moisture and heat transfer (which is important for arid and semi-arid areas), the soil-root hydraulics is important to link soil moisture states with land surface fluxes, the soil-groundwater interaction is often neglected in climate models while its importance for affecting land surface flux exchanges is non-trivial.

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)?

LoCo - LoCo is at the core of this question, 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 beyond the 1-D paradigm, questions of horizontal scale and transport in the PBL will become important as well.

GLAFO - This is a key research activity and focus of GLAFO. First results are expected soon. New metrics will be available to investigate the feedback between surface fluxes and ABL development including entrainment.

GABLS - The project will utilize the advanced capabilities of the GLAFO sites to assess how well models represent the detailed turbulent structure of the atmospheric boundary layer.

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 enhanced 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.

SoilWat - SoilWat is paying 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 Third Pole Environment (TPE) on affecting ABL, due to the unique behaviour of its land surface processes, largely as a result of its high altitude. In this context, SoilWat is collaborating with the GASS LS4P project. SoilWat is also contributing to the GABLS project.

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 - Research on the link between land surface states/fluxes (e.g. related to soil moisture) 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, existing Earth Observation data are not yet sufficient to enable the observation-based quantification of such interactions. A prime example is the Tibetan Plateau, where the SMOS/SMAP soil moisture 'daily' products are only available for the 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.

SIF-MIP - The 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?

SIF-MIP - We have envisioned approaches for examining land-atmosphere interactions by coupling a subset of our models to atmospheric models, such as the Climate Modeling Alliance (CLIMA)

LoCo - By developing and employing integrated metrics to confront our models, facilitated by improved observations (for both evaluation and assimilation).

GABLS - The project will exploit the comprehensive observations at the GLAFO sites, including the state of the land surface to assess the physics of land-atmosphere coupling and the role of surface heterogeneities.

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.

SoilWat - This project 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.

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?

SIF-MIP - The global sensitivity experiments, using coupled carbon-water cycle data assimilation and factorial simulations driven by climate and CO2, show the impact of anthropogenic forcing on the water budget at grid to global scale. The analysis shows impacts to water storage, as well as vertical and lateral flux terms including evaporation, transpiration, sublimation, and runoff (surface and subsurface). We find the following hydrological changes associated with changing CO2 and climate forcing: A) Increasing atmospheric CO2 levels lead to increased plant growth, yet there is reduced soil water loss, driven by reduced transpiration, increased soil water storage, and reduced subsurface runoff. B) Climate trends, including increased warming, leads to increased soil water loss, driven by reduced plant growth, increased mortality, and increased evaporation and surface to subsurface runoff

SoilWat - Since anthropogenic forcing is represented by elevated atmospheric CO2 concentration, this point is largely linked to photosynthesis, and the sensitivity of stomatal conductance to CO2 concentrations (which of course will also influence transpiration and hence affect water availability), and the plant's acclimation to increased CO2 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 CO2 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.

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?

Irrigation - These questions are at the heart of the Irrigation cross-cut project, albeit currently being explored at the more local scale (see also under LoCo)

SIF-MIP - The experiments could in principle be extended to agricultural sites to examine impacts of land management on carbon, and vice versa

LoCo - There are direct connections of LoCo with irrigation practices, groundwater withdrawal, land 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 WEC and NWP/GCM predictive capabilities. Tricia Lawston-Parker et al. are leading the irrigation cross-cut activity within GEWEX 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.

GLAFO - This is to be studied with LAFO long-term measurements in Stuttgart, Germany, as this is an agricultural site.

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?

SIF-MIP - Fully coupled runs as described above can be used to assess changes in water availability. This will be a key activity in 2025.

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 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 and land cover will change the soil hydraulic and thermal properties, which will in turn impact the land surface water, energy and carbon fluxes.

Other Key Science Question

1. What are the strongest drivers of the underwhelming performance of land surface models in the modeling of turbulent surface fluxes and how can a combination of process understanding, parameterization development, benchmarking, observations (remote and in-situ) and Machine Learning be used to address these weaknesses?

2. How do water, energy, carbon fluxes within the soil and vegetation couple, how do they respond to climate change, and how do they feed back on land-atmosphere interactions? How do the uncertainty in the representation of the soil and vegetation properties affect the modeling of these processes? What novel approaches can we use to find these sub-surface properties on the global scale leveraging observations and machine learning
3. Address the sub-optimal performance of MOST via development and testing of new parameterizations. This is related to the first one but requires special and dedicated attention since indications point to it being an Achilles heel in land-atmosphere coupling.

Contributions to WCRP including the WCRP Light House Activities

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 approaches in integrated, process-level fashion (not old school one-at-a-time, 500mb heights, etc.).
- CLASP is also strongly connected as it seeks to improve modeling of high-resolution land-surface coupling; this directly involves improved land surface modeling and atmospheric modeling. The applications span from Large Eddy Models up to GCMs.
- ML4LM is aiming to understand how we can leverage Machine Learning to accelerate the advances in the modeling of land surface modeling which is fundamental if we are to keep pace with the increases in spatial resolution in the near term.
- Scientists within SoilWat are working towards a Soil-Plant Digital Twin

Explaining and Predicting Earth System Change:

- LoCo has relevance here in identifying persistent errors in GCMs via coupled metrics and identifying where observational network improvements need to be made.
- SoilWat aims to understand how soils are modeled within the Earth system and how the changes in the soils will impact weather and global climate.
- CLASP's interests in revisiting coupling in revisiting the coupling of land-atmosphere models will require a push towards an improved understanding of fine-scale turbulent coupling and thus Earth system understanding.

Global Precipitation Experiment (GPEX):

- CLASP's goals to improve the heterogeneous coupling between the land surface and the atmosphere has large implications for how the land surface interacts with the atmosphere through microscale and mesoscale circulations. These processes in turn have an impact on the development of shallow cumulus and convective precipitation which remains a large source of uncertainty.
- GLAFO's efforts to more adequately measure the PBL provides a key opportunity to confront our Earth system models with actual vertical profiles of states and fluxes; this in turn will lead to improvements in PBL and cloud schemes and ultimately precipitation predictability.

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

- GLAFO: WCRP RCP TeamX, LIAISE; AmeriFlux; Critical Zone Observatories (CZos); NASA Hydrological Testbed, MOSAI, LIAISE, SIRTA in France

- 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
- WGNE: Presentations and discussions on the path towards use of GLAFO-type data to evaluate coupled land-atmosphere models and to improve the modeling of surface fluxes
- CLASP: DOE ASR/ARM, AMF3-BNF, WHYMSIE, MOSAI
- S2S: Projects led by LoCo WG members to NASA and NOAA programs
- SoilWat will potentially contribute to the evaluation/assessment of crop/agriculture water productivity, as such contributing to 'Water for the Food Baskets', 'farm to fork'.
- SoilWat can help to provide more accurate estimates of land surface states/fluxes that will help improve prediction of 'Extremes'
- Outside bodies: the SoilWat initiative is intricately linked to the activities by the International Soil Modelling Consortium (ISMC):https://soil-modeling.org.
- LS4P led by Yongkang Xue
- ECMWF S2S project led by Fredric Vitart

Workshops and Meetings

List of Workshops and Meetings Held in 2024

- GLASS Panel Meeting in Sapporo, Japan, July 6th, 2024
- GABLS meeting, Feb. 6th, 2024, online
- Irrigation CC Virtual Meeting – April 10, 2024
- Irrigation CC Virtual Meeting – July 23, 2024
- Irrigation CC Virtual Meeting – October 8, 2024
- ISMC-SoilWat Breakout "Soil Thermal Properties Work Group Meeting"
- ISMC-SoilWat Breakout "PTF Work Group Meeting"
- ISMC-SoilWat Breakout "Soil Carbon Work Group meeting"
- ISMC-SoilWat Breakout "Soil Process Evaluation Metrics"
- ISMC-SoilWat Breakout “Soil Math”
- ISMC Annual Conference 2024, Tianjin
- LoCo L-A sessions convened at AMS24 and AGU24
- Visit of potential GLAFO site in Brazil, March 2024
- GLAFO meeting at EGU, Vienna, Austria, April 2024
- PLUMBER2 results and working group workshop, 7 July, Sapporo
- CLASP Virtual meeting - September 2024
- CLASP/MOSAI Virtual meeting - November 2024
- International Symposium on Energy and Water Exchanges in Land-Atmosphere Interactions - July 2024, Busan, South Korea

List of Workshops and Meetings Planned in 2025 and 2026

- LAFI and GLAFO presentations are EGU in Vienna, April 2025
- LAFI/GLAFO Spring School, May 2025
- GLASS Panel Meeting in Reading, UK, July 16th-18th, 2025

- CLASP bimonthly virtual meetings
- LoCo - L-A sessions at AMS-25 and AGU-25
- Irrigation cross-cut quarterly meetings
- ML4LM monthly webinar series (https://www.gewex.org/project/ml4lm/2025-ml4lm-webinar-series/)
- ISMC-SoilWat Breakout sessions
- ISMC-GEWEX-SoilWat meeting in Reading, UK, July 14th-16th, 2025 (https://www.gewexevents.org/meetings/ismc-soilwat2025/)

Other Meetings Attended On Behalf of GEWEX or Panel in 2024

- WGNE WGSIP meeting in Toulouse, France, November 2024
- MOSAI workshop meeting in Toulouse, France, June 2024
- EGU 2024/AGU 2024/AMS 2025

Publications during Reporting Period

List of Key Publications

Abramowitz, G., Ukkola, A., Hobeichi, S., Cranko Page, J., Lipson, M., De Kauwe, M. G., Green, S., Brenner, C., Frame, J., Nearing, G., Clark, M., Best, M., Anthoni, P., Arduini, G., Boussetta, S., Caldararu, S., Cho, K., Cuntz, M., Fairbairn, D., Ferguson, C. R., Kim, H., Kim, Y., Knauer, J., Lawrence, D., Luo, X., Malyshev, S., Nitta, T., Ogee, J., Oleson, K., Ottlé, C., Peylin, P., de Rosnay, P., Rumbold, H., Su, B., Vuichard, N., Walker, A. P., Wang-Faivre, X., Wang, Y., and Zeng, Y.: On the predictability of turbulent fluxes from land: PLUMBER2 MIP experimental description and preliminary results, Biogeosciences, 21, 5517–5538, https://doi.org/10.5194/bg-21-5517-2024, 2024.

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Hsu, H., P. A. Dirmeyer and E. Seo, 2024: Exploring the mechanisms of the soil moisture-air temperature hypersensitive coupling regime. Water Resour. Res., 60, e2023WR036490, doi: 10.1029/2023WR036490.

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2.4.1 GLASS Rapporteurs Report

Panel: Global Land-Atmospheric System Studies (GLASS) Panel
Rapporteur(s): Martin Best, Li Jia, Manon Sabot

Adherence to GEWEX and Panel's objective(s)

The objectives of the GLASS panel are very well aligned with those of GEWEX. The activities within GLASS aim to understand the terrestrial water stores and the fluxes of energy, water and carbon between the land and the atmosphere. This is done through both observations, and modelling studies and includes aspects such as soil and vegetation processes, the impacts of heterogeneity, land-atmosphere interactions and human influences such as irrigation.

Achievement of annual goals for this reporting period

- Steps have been taken to reduce the size of the GLASS panel and refocus activities. Four panel members have been retired, with just one new panel member added. Plans to reduce the number further will be actioned when appropriate.
- GLASS currently has 10 projects addressing our understanding of key processes on the land surface and land-atmosphere exchange. Some of these have been running for a long time and are looking to sunset.
- A new structure for GLASS projects has been identified which organizes projects within a framework of three key themes: Observations/Benchmarking, Process Understanding and Model Development.

Major accomplishments and results in reporting period

- The PLUMBER2 project has had a paper published on its key findings, including that the latent heat flux and net ecosystem exchange of CO2 are better predicted than the sensible heat flux. Also land models implemented within Earth System Models appear to perform better at representing surface fluxes than stand-alone ecosystem models.
- The SoilWat model intercomparison project has identified that individual land surface models respond very differently to changes in soil parameters and can respond counter-intuitively due to the complex interactions of infiltration, soil evaporation and plant transpiration.
- A network of Doppler Lidars, as planned for level 4 GLAFO sites, enables the detection of secondary circulations driven by km-scale surface heterogeneities. This provides a path towards the evaluation and improvement of sug-grid land-atmosphere coupling schemes.

Arisen or noted science issues

- Subsequent analysis of the PLUMBER 2 project results has identified that land models are not consistent with observations in terms of the phase lag between the net radiation and soil heat flux. All models have the opposite sign to the observations.
- Conclusions from the SoilWat project include that pedo-transfer functions for soil parameters have focused on refining and advancing the regression models but have neglected more mechanistic aspects. Most soil systems are not represented by parameterized pedo-transfer functions because studies have been mostly for agricultural soils in temperate climates.

Emerging Science

A new focus is emerging within GLASS to include the study of machine learning for land modelling. A webinar series throughout 2025 is planned to jump start this initiative and bring the global community together.

Future plans

- A model intercomparison project of space-time patterns in land surface temperature is being devised. This will include revisiting turbulence parametrizations as part of the CLASP project.
- The panel is looking to reinvigorate an urban land-atmosphere interactions effort, following on from Urban PLUMBER, and will look to appoint an appropriate new panel member.
- Plans for a Pan-GLASS meeting are being put together.

Recommendations to Panel

- Current GLASS projects and activities could be considered within a three-step process. The first step would be key science working groups where embryo ideas can be developed, and the enthusiasm of researchers can be encouraged. This could then lead to new project ideas that would form part of step 2: active GLASS projects. The key for an active GLASS project would be that the project would not happen if GLASS did not exist. Step 3 would then be the continued analysis of project results once the active project has been completed. This subsequent analysis could identify new embryo ideas that would feed back into step 1. Whilst GLASS can help to facilitate this structure, the suggestion is that only step 2 active projects would be the actual GLASS activities.
- A number of general science areas should be identified and form the basis of key science working groups that would define step 1 in the above recommendation. This would enable all aspects of the land surface to be considered as potential GLASS activities without them being active GLASS projects. As GEWEX is an unfunded activity, this would enable the GLASS projects to be driven bottom up by enthusiastic scientists that have secured funding for their project.
- The proposed Pan-GLASS meeting could focus around the general science areas in the above recommendations and link into other GEWEX panels as well as other WCRP projects.

Considerations for SSG

The current panel reporting has quite a bit of duplication, but there is no opportunity for the panel to report on how they have addressed feedback from the SSG. It would be good to include a section in the annual report from each panel on this topic.

Additional Remarks

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2.5 CLIVAR/GEWEX Monsoon Panel

Full Panel Name (Acronym) : MP
Reporting Period : 01 January - 31 December 2024
Starting Date : June 2014
End Date (where appropriate) : N/A
URL : https://impo.tropmet.res.in/wcrp-monsoon.html

Membership

Co-Chair(s) and Term Dates : Leila CARVALHO; 2020– Present
Suryachandra Rao ANGULURI; 2019– Present

Members and Term Dates : Rondrotiana BARIMALALA; 2021– Present
Annalisa CHERCHI; 2022– Present
Thea TURKINGTON; 2022– Present
Hui SU; 2023– Present
Hiroshi TAKAHASHI ; 2023– Present
Jhan-Carlo ESPINOZA; 2024– Present
Samson HAGOS; 2024– Present
Satyaban Bishoyi RATNA; 2024– Present
Hanh NGUYEN; 2025– Present
Vasubandhu MISRA; 2025– Present
Fengfei SONG; 2025– Present
Luis BRITO-CASTILLO; 2025– Present

Panel Objectives, Goals and Accomplishments during Reporting Period

Overall Panel Objective(s):

Overarching Goal: Advancing understanding of monsoon variability and improving its prediction with observations and modelling as cornerstones of research activities

- Enhanced emphasis on linkages across scales and physical processes
- Seek for new methods to enhance monitoring, advance diagnostics and improve models
- Development of more elaborated process studies coordinated with modelling activities
- Empowering the next generation of scientists around the world to advance our knowledge of monsoon systems, in key regions of interest.

List of Panel Goals

Identify bottlenecks to achieve improved skills in representing all monsoons in dynamical models, from synoptic (weather) to large-scale (climatological scale), with great emphasis on extremes. These activities include:

- Assess the skill of dynamical models in simulating rainfall in regional monsoons and identify bottlenecks for further improvement.
- Improve understanding of dynamical and physical processes associated with extreme events in monsoon regions and identify deficiencies and gaps in capturing these extremes in present-day models.
- Support Research to Operations (R2O) activities to help the Regional Climate Outlook Forums (RCOFs) and operational meteorological services.

- Communicate existing products and provide guidance on their (adequate) application and limitations focusing on the operational and (relevant) impacts communities and participate in relevant training activities.
- Build Capacity through working groups by promoting Early Career Scientist (ECS) representation in the working groups and subgroups.

List of 2 to 3 Key Results

- Involvement MP/WG members in STIPMEX Workshop held during 3-7 June 2024 at IITM Pune:
- Leila Carvalho (MP Co-chair) was a member of Scientific Steering Committee (SSC)
- Dr. Parthasarathi Mukhopadhyay (WG-AAM member) played a key role in the conceptualization of STIPMEX as a member of SSC and in the organization of the workshop a member of Local Organizing Committee (LOC).
- Suryachandra Rao (MP Co-chair) chaired the Session X on "New approaches for extreme weather events prediction" on 6th June 2024.
- Dr. Parthasarathi Mukhopadhyay (WG-AAM member) Co-chaired Session XIV on Stakeholders' Discussion on Renewable Energy & Weather Forecasts on 7th June 2024.
- Dr. Parthasarathi Mukhopadhyay (WG-AAM member) delivered a Lead Oral talk on "A convection permitting model: IITM HGFM to improve High Impact weather prediction" in Session X on 6th June 2024
- Dr. Raghavendra Ashrit (WG-AAM member) delivered a Lead Oral online talk on "Extreme Daily Rain: Forecasting & Verification Challenges" in Session X on 6th June 2024
- Dr. Satyaban Ratna (MP Member) was member of the LOC of STIPMEX, and he co-chaired the Session VIII on "Extreme weather events and prediction" 6th June 2024.
- Members of the MP and working groups were actively involved in the 9th GEWEX OSC:
- MP Co-chairs (Prof. Leila Carvalho and Dr. Suryachandra Rao) were members of the Program Committee of OSC for Planning and organizing of the conference program.
- Drs. Suryachandra Rao (MP Co-chair), Hiroshi Takahashi (MP) and Hugh Zhang (WG-AAM) were convenors of the Session 10 of the 9th GEWEX OSC on "Monsoons (Special Session celebrating 150 years of IMD)" and Drs. Hiroshi Takahashi and Hugh Zhang co-chaired the session held on 10th July 2024.
- Dr. Hiroshi Takahashi (MP) presented a paper on "Impact of Spring Land-Surface Conditions over the Tibetan Plateau on the Early Summer Asian Monsoon using an AGCM Large Ensemble".
- Dr. Samson Hagos (MP) presented a paper on "Horizontal Vorticity Mixing as a Sub-Grid Parameterization for Convection Permitting Models".
- Dr. Hugh Zhang (WG-AAM) presented a paper on "CCRS Research towards Improving Modelling and Forecasting Convective Weather over the Maritime Continent".
- Dr. Joseph Basconcillo (WG-AAM) presented a paper on "Characterizing the Southwest Monsoon Season in the Philippines Using Multiple Localized Monsoon Indices".
- Dr. Shiromani Jayawardena (WG-AAM) presented a paper on "Pre-Monsoon Disturbances and Extreme Rainfall: Enhancing Early Warning Systems in Sri Lanka".
- The 8th WMO International Workshop on Monsoons (IWM-8) is being organized jointly by the Indian Institute of Tropical Meteorology (IITM), Pune, Ministry of Earth Sciences (MoES), Government of India, the WWRP's Working Group on Tropical Meteorology Research (WGTMR) and the CLIVAR/GEWEX Monsoons Panel in cooperation with the India Meteorological Department and the International Monsoons Project Office (IMPO) during 17-21 March 2025 in Pune, India. The involvement of MP/WGs members in IWM-8 are the following:

- 5 members of the Monsoons Panel (Prof. Leila Carvalho, Dr. Suryachandra Rao Anguluri, Dr. Annalisa Cherchi, Dr. Samson Hagos and Dr. Rondrotiana Barimalala), 3 members of WG-AFM (Dr. Akintomide Akinsanola, Dr. Neil Hart and Dr. Masilin Gudoshava), 2 members of WG-AAM (Dr. Tieh-Yong Koh and Dr. Shiromani Jayawardena) and 3 members of WG-AMM (Prof. Alice Grimm, Dr. Caio Augusto dos Santos Coelho and Prof. Michelle Simões Reboita) are playing a key role as the members of the International Scientific Committee (ISC) of IWM-8. These members played an active role in the evaluation of the abstracts submitted to the workshop and few members are identified to deliver Invited Talks in the workshop.
- Thirty (30) Abstracts with MP/WG members as lead author/co-authors have been accepted for Oral/Poster presentation in the workshop

Other Science Highlights

- WG-AFM members (Drs. Akintomide Akinsanola, Aissatou Faye and Ross Dixon) were co-chairs of the Session 13B on "African Climate Change and Variability" at the 2024 American Meteorological Society (AMS) Annual Meeting, at Baltimore, MD, which provided a platform to share cutting-edge research on African climate systems.
- 4 members of WG-AFM (Drs. Akintomide Akinsanola, Aissatou Faye, Ross Dixon and Ismaila Diallo) and Dr. Samson Hagos (MP Member) participated in the UCAR Africa Initiative Workshop held during 21-22 March 2024 at Center Green, Boulder, CO, USA and online. Drs. Akintomide Akinsanola and Samson Hagos were Chairs/Facilitators of the Group Discussions on Climate and Weather respectively.
- Documentation of the unusual characteristics of monsoons 2022 and 2023: A specific activity was undertaken to compare the boreal summer monsoon in these two years. An article entitled "Asian Summer Monsoon Variability during 2022–2023: Beyond Canonical Teleconnection Patterns" was written up and published in the *GEWEX Quarterly, Vol. 34, No. 3 Quarter 3, 2024*.
- WG-AFM members were involved in writing-up a review paper entitled "Modeling of Precipitation over Africa: Progress, Challenges, and Prospects" for the journal *Advances in Atmospheric Sciences.*

Panel Activities during Reporting Period

List of Panel Activities and Main Result

Organizational Activities

The Sixth Session of CLIVAR/GEWEX Monsoons Panel was held on 11th July 2024 during the 9th GEWEX/OSC at Sapporo, Japan in hybrid mode (with 4 members attending in-person and 4 online). A special hybrid meeting of MP and WG-AAM members (with 5 members attending in-person and 7 online) was also organized on 11th July 2024. Xubin Zeng (Co-chair, GEWEX SSG), Francois Engelbrecht (Co-chair, CLIVAR SSG) and Hindumathi Palanisamy (WMO Secretariat) attended the meeting in-person as special invitees and gave their valuable suggestions/comments. Sonya Legg (Co-chair, CLIVAR SSG) also attended the meeting online and gave her valuable comments/suggestions. Photos displaying the session is given in Appendix-I. The minutes of the session is available in Page "MoM:2024" of Section "MP Meeting Minutes" in the Monsoons Panel Notebook
In addition, MP held 5 virtual meetings in 2024 (on 23rd January 4th April 10th June 13th September and 12th November), which enabled discussions on the cross-panel activities, 2025 Membership updates, activities of regional WGs and future work plans. A special meeting between the Monsoons Panel (MP) and the Working Group on American Monsoons (WG-AMM) was also held on 20th February 2024 to understand the issues faces by the working group. The minutes of all meetings are available in Page "MoM:2024" of Section "MP Meeting Minutes" in the Monsoons Panel Notebook

- WG-AFM held 3 virtual meetings in 2024 (29th February 30th April and 26th November) to discuss on the writing of a review article on "Climate Modeling of Precipitation over Africa", the activities of

their 3 sub-groups (Viz., South & East Africa, West Africa, and Central Africa) and 2025 Membership revisions.

- WG-AAM held 4 virtual meetings (on 15th January 2nd May 12th September and 21st November) to discuss on the activities of the group and its 3 sub-groups (Viz., Monsoon Processes and Teleconnections; R2O for monsoon seasons in SE Asia; High Impact Weather Events), 2025 Membership updates and on the Asian/Australian (summer) Monsoon 2024.
- WG-AMM had email exchanges and a few online meetings among its members to discuss their activities.

MP was actively involved in the selection and appointment of the 3 new members to the panel (Dr. Samson Hagos, Dr. Jhan-Carlo Espinoza and Dr. Satyaban Bishoyi Ratna) in February 2024.

MP was also actively involved in the 2025 membership revisions in WG-AAM, WG-AFM and WG-AMM. 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: 6, Male: 8)
- Co-Chairs: Prof. Leila M.V. Carvalho and Dr. Suryachandra Rao Anguluri
- Webpage: https://impo.tropmet.res.in/wcrp-monsoon.html
- Working Group on Asian-Australian Monsoons (17 members; Female: 5, Male: 12)
- Co-Chairs: Dr. Tieh Yong Koh and Dr. Lin Wang
- Webpage: https://impo.tropmet.res.in/mpwg-aam-members.html
- The 2025 Membership renewal of WG-AAM was approved by MP on 15th October 2024. The 5 new members are:
- Dr. Hui Su (MP Member from HKUST, China)
- Dr. Hiroshi Takahashi (MP Member, Tokyo Metropolitan University, Japan)
- Dr. Tim Cowan (BoM/University of Southern Queensland, Australia)
- Dr. Zizhen Dong (Yunnan University, Kunming, China)
- Dr. Maheswar Pradhan (IITM, Pune, India)
- Five existing members Drs. H. Annamalai, Suryachandra Rao A., Usha Tune, Huqiang Zhang and P. Mukhopadhyay are being rotated off on their request.
- Working Group on African Monsoons (21 members; Female: 8, Male: 13)
- Co-Chairs: Dr. Rondrotiana Barimalala and Dr. Akintomide Afolayan Akinsanola
- Webpage: https://impo.tropmet.res.in/mpwg-afm-members.html
- WG-AFM is being reconstituted under the new Co-chairs (Paul-Arthur Monerie and Masilin Gudoshava). An Open Call for new Members to the CLIVAR/GEWEX Monsoons Panel's Working Group on African Monsoons has been advertised in IMPO webpage and circulated the advertisement to other networks.
- Working Group on American Monsoons (14 members; Female:5, Male: 9)
- Co-Chairs: Dr. Alice Grimm (the other Co-chair (Ruth Cerezo-Mota) has resigned)
- This WG is being reconstituted under the new Co-chairs (Dr. Caio Augusto dos Santos Coelho and Prof. Michelle Simões Reboita)
- Webpage: 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 Carvalho (MP Co-chair) participated (online) in the 29th Session of CLIVAR SSG on 29th February 2024 and presented the recent activities of MP and its Regional Working Groups.
- Suryachandra Rao (MP Co-chair) participated in-person in the 36th GEWEX SSG meeting in-person during 22-26 April 2024 in Budapest, Hungary and presented the recent activities of MP and its Regional Working Groups
- Leila Carvalho (MP Co-chair) participated in the 45th WCRP JSC meeting online on 27th May 2024 and presented an update on the activities of MP & IMPO.
- Leila Carvalho (MP Co-chair) participated (online) in the WMO - Regional Association II – Asia (WMO RA-II) 19th Hangzhou Asian Games Research Development Project on Convective-scale Ensemble Prediction and Application on 15th June 2024 and presented the activities of MP and its Regional Working Groups
- Involvement MP/WG members in STIPMEX International Workshop held during 3-7 June 2024 at IITM Pune:
- Leila Carvalho (MP Co-chair) was a member of Scientific Steering Committee (SSC)
- Dr. Parthasarathi Mukhopadhyay (WG-AAM member) played a key role in the conceptualization of STIPMEX as a member of SSC and in the organization of the workshop a member of Local Organizing Committee (LOC).
- Suryachandra Rao (MP Co-chair) chaired the Session X on “New approaches for extreme weather events prediction” on 6th June 2024.
- Dr. Parthasarathi Mukhopadhyay (WG-AAM member) Co-chaired Session XIV on Stakeholders’ Discussion on Renewable Energy & Weather Forecasts on 7th June 2024.
- Dr. Parthasarathi Mukhopadhyay (WG-AAM member) delivered a Lead Oral talk on “A convection permitting model: IITM HGFM to improve High Impact weather prediction” in Session X on 6th June 2024
- Dr. Raghavendra Ashrit (WG-AAM member) delivered a Lead Oral online talk on “Extreme Daily Rain: Forecasting & Verification Challenges” in Session X on 6th June 2024
- Dr. Satyaban Ratna (MP Member) was member of the LOC of STIPMEX, and he co-chaired the Session VIII on “Extreme weather events and prediction” 6th June 2024.
- Members of the MP and working groups were actively involved in the 9th GEWEX OSC:
- MP Co-chairs (Prof. Leila Carvalho and Dr. Suryachandra Rao) were members of the Program Committee of GEWEX OSC for Planning and organizing of the conference program.
- Drs. Suryachandra Rao (MP Co-chair), Hiroshi Takahashi (MP member) and Hugh Zhang (WG-AAM Member) were convenors of the Session 10 of the 9th GEWEX OSC on “Monsoons (Special Session celebrating 150 years of IMD)” which was held on 10th July 2024 at Sapporo, Japan. More details on the session can be found in Appendix-II.
- Dr. Hiroshi Takahashi (MP) presented a paper on “Impact of Spring Land-Surface Conditions over the Tibetan Plateau on the Early Summer Asian Monsoon using an AGCM Large Ensemble”.
- Dr. Samson Hagos (MP) presented a paper on “Horizontal Vorticity Mixing as a Sub-Grid Parameterization for Convection Permitting Models”.
- Dr. Hugh Zhang (WG-AAM) presented a paper on “CCRS Research towards Improving Modelling and Forecasting Convective Weather over the Maritime Continent”.
- Dr. Joseph Basconcillo (WG-AAM) presented a paper on “Characterizing the Southwest Monsoon Season in the Philippines Using Multiple Localized Monsoon Indices”.
- Dr. Shiromani Jayawardena (WG-AAM) presented a paper on “Pre-Monsoon Disturbances and Extreme Rainfall: Enhancing Early Warning Systems in Sri Lanka”.

- WG-AFM members (Drs. Akintomide Akinsanola, Aissatou Faye and Ross Dixon) were co-chairs of the Session 13B on “African Climate Change and Variability” at the 2024 American Meteorological Society (AMS) Annual Meeting, at Baltimore, MD, which provided a platform to share cutting-edge research on African climate systems.
- 4 members of WG-AFM (Drs. Akintomide Akinsanola, Aissatou Faye, Ross Dixon and Ismaila Diallo) and Dr. Samson Hagos (MP Member) participated in the UCAR Africa Initiative Workshop held during 21-22 March 2024 at Center Green, Boulder, CO, USA and online. Drs. Akintomide Akinsanola and Samson Hagos were Chairs/Facilitators of the Group Discussions on Climate and Weather respectively.
- Dr. Satyaban Ratna (MP Member) as a Secretary of the Indian Meteorological Society-Pune Chapter (IMSP), played a key role in the organization of the Annual Monsoon Workshop to review the Indian Summer monsoon 2024
- Dr. Satyaban Ratna (MP Member) participated (Online) in the WMO RA II Research Activities workshop held in Beijing, China during 15-17 July 2024 and highlighted the Monsoons Panel activities during the discussions.
- The 8th WMO International Workshop on Monsoons (IWM-8) is being organized jointly by the Indian Institute of Tropical Meteorology (IITM), Pune, Ministry of Earth Sciences (MoES), Government of India, the WWRP’s Working Group on Tropical Meteorology Research (WGTMR) and the CLIVAR/GEWEX Monsoons Panel in cooperation with the India Meteorological Department and the International Monsoons Project Office (IMPO) during 17-21 March 2025 in Pune, India. The involvement of MP/WGs members in IWM-8 are the following:
- 5 members of the Monsoons Panel (Prof. Leila Carvalho, Dr. Suryachandra Rao Anguluri, Dr. Annalisa Cherchi, Dr. Samson Hagos and Dr. Rondrotiana Barimalala), 3 members of WG-AFM (Dr. Akintomide Akinsanola, Dr. Neil Hart and Dr. Masilin Gudoshava), 2 members of WG-AAM (Dr. Tieh-Yong Koh and Dr. Shiromani Jayawardena) and 3 members of WG-AMM (Prof. Alice Grimm, Dr. Caio Augusto dos Santos Coelho and Prof. Michelle Simões Reboita) are playing a key role as the members of the International Scientific Committee (ISC) of IWM-8. These members played an active role in the evaluation of the abstracts submitted to the workshop and few members are identified to deliver Invited Talks in the workshop.
- Thirty (30) Abstracts with MP/WG members as lead author/co-authors have been accepted for Oral/Poster presentation in the workshop (More details are given in Appendix-III).
- Scientific Results from WG-AAM
- Monsoon Processes and Teleconnections (MPT) subgroup:
- The ways to proceed with the scientific collaborations within the subgroup were identified to be based on ongoing research and projects of subgroup members with contributions to subgroup members or larger communities who have interest. Three potential directions of collaboration that were identified are:
- Teleconnections between Arctic Sea ice and East Asian cold extremes,
- Influences of cold surge on East and Southeast Asia with new cold surge features
- Monitoring and understanding heavy rainfall (including typhoons) over Southeast Asia and Northwestern Pacific.
- Research to Operations for monsoon seasons in SE Asia (R2O) subgroup:
- A Southeast Asian Monsoon Index has been developed to characterize the onset, progress and termination of summer and winter monsoons in Southeast Asia. The results were presented at the 9th GEWEX OSC meeting held in Sapporo, Japan, in July 2024 a WG member. One paper based on this work is under preparation for submission to an international journal by the end of 2024. This

work is currently extended by re-examining the persistence and strength of monsoon winds in the delineation of the progression of monsoon peaks in Southeast Asia.

- High Impact Weather Events (HIW) subgroup
- Development of a paper currently titled “What makes a good weather warning?”, aiming for a completed draft in Q1 2025. The aim of the paper is to cross-compare weather warnings released by national met agencies across monsoonal Asia. They have brought on board a number of employees from these agencies and have made good progress on a paper draft, which includes comparison of warnings for specific event types (e.g., heatwaves and tropical cyclones) as well as summary tables for website structure and traffic for each agency. They will conclude with a detailed discussion noting both common themes (good or bad!) and best practices, as well as difficulties faced by agencies and our recommendations for the future.
- Documenting the unusual characteristics of monsoons 2022 and 2023
- Following on from previous discussions on the unusual characteristics of the 2022 summer monsoon season, and since 2023 was also a somewhat unusual year for the boreal summer monsoons, a specific activity was undertaken to compare and contrast the boreal summer monsoons in these two years. An article was written by a subset of the WG members, led by Dr Ajaya Mohan, and submitted on behalf of the WG-AAM to GEWEX Quarterly for publication in the autumn edition and is now published. An abstract on this has also been submitted to the IWM-8.
- Reviewing the Asian Australian monsoons in 2024
- As part of the WG’s continued monitoring and discussing of the boreal and austral monsoon conditions, extreme events, and large-scale drivers for the Asian Australian monsoon region, a special meeting was held on 21st November 2024 to review the monsoons in 2024.
- Scientific Results from WG-AFM:
- The West Africa Subgroup made substantial progress in analyzing the representation of mesoscale convective systems over West Africa using DYAMOND data. Key findings are now available, offering valuable insights into convective system dynamics in the region.

<u>Scientific Capacity Building and Career Support</u>

- WG-AFM played a key role in the successful organization of the Joint WCRP/ WWRP Webinar Series on African Monsoons, held online on 6th March 2024, which featured talks by eminent scientists, Prof. Prof. Michela Biasutti (Climate Change in the Sahel: The Past and the Future) and Dr. Samson Hagos (Synchronization of the Recent Decline of East African Long Rains and Northwestern Asian Warming). The WG-AFM Co-chairs Drs. Rondrotiana Barimalala and Akintomide Akinsanola co-chaired the webinar. A screenshot of the in-progress webinar is displayed in Appendix-IV. Out of the 138 registered attendees, 74 attended the webinar. Video recording of the webinar has been made available in IITM YouTube channel for wider reach & publicity, which has 250 views till date.
- WG-AMM played a key role in the successful organization of the Joint WCRP/ WWRP Webinar Series on American Monsoons, held online on 24th April 2024, which featured talks by eminent scientists, Prof. Pedro Leite da Silva Dias (Challenges for the South American monsoon predictability) and Dr. Salvatore Pascale (The North American monsoon: current scientific issues and perspective for the future). Prof. Alice Grimm (WG-AMM Co-Chair) chaired the webinar. A screenshot of the in-progress webinar is displayed in Appendix-IV. Out of the 126 registered attendees, 53 attended the webinar. Video recording of the webinar has been made available in IITM YouTube channel for wider reach & publicity, which has 142 views till date.
- Dr. Lin Wang helped to organize a domestic Young Scientist Workshop on Extreme Weather and Climate Events in September 2024 in Beijing. The workshop reviewed the 2024 summer monsoon status and its prediction, as well as dynamics and new tools and technologies in monsoon observation, research, and prediction.

- An early-career scientist activity was organized during the ICDM Workshop 2024 in October in Beijing, where Dr. Lin Wang was a co-chair of the workshop. About 50 early-career scientists communicated with nine senior and mid-career scientists face-to-face in three groups. The discussed topics include but are not limited to paper writing, selection of research topics, career development, and balance between work and life, especially for female scientists.
- Under the CBIT (Capacity Building Initiatives for Transparency) project, Dr Shiromani Jayawardena (WG-AAM) conducted several workshops and training sessions to strengthen climate data monitoring, reporting, and adaptation strategies. The focus remains on equipping officials with advanced data tools and methodologies to meet transparency and adaptation goals, particularly in the Agriculture, Forestry, and other land use (AFOLU) sectors in Sri Lanka, aligned with the Paris Agreement.
- Michelle Reboita (WG-AMM) is a coordinator of "Environmental Connection", a radio program in FM band to discuss environmental topics. The programs are recorded - one example: https://conexaoitajuba.com.br/defesa-civil-alerta-para-possibilidade-de-fortes-chuvas-em-itajuba-e-regiao/

Knowledge exchange

- Several of the WG-AAM members are regular contributors to the Regional Climate Outlook Forums for the Asian Australian region (SASCOF, ASEANCOF), 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 GEWEX Open Science Conference in Sapporo, Japan, 7-12 July 2024, with 4 being funded by CLIVAR/GEWEX.
- The WG-AAM has been supporting the Monsoons Panel activity to compile a special issue on the Global Monsoons for Advances in Atmospheric Sciences. Some papers have been submitted. In addition,
- Dr. Lin Wang is working on a review of the Asian summer monsoon
- Dr. Hiroshi Takahashi is working on a review about land-atmosphere interactions over the Asian monsoons.
- Dr. Tim Cowan will be approached for a review of the Australian monsoon.
- The APARC/ACAM group might contribute, and the WG may encourage some of the IWM-8 contributors to submit papers to the AAS collection.
- Several WG-AAM members attended and presented at the AOGS 2024 at Pyeongchang, Gangwon-do, South Korea during 23-28 June 2024.
- Five MP members and eight WG members joined the International Scientific Committee (ISC) for the Eighth WMO International Workshop on Monsoons (IWM-8) being during 17-21 March 2025 at Pune, India. They were involved in the evaluation of submitted abstracts to IWM-8.
- Suryachandra Rao (MP) delivered a talk on "Monsoon Forecasts: Skills and Bottlenecks" in the workshop on Moist Convective Dynamics of Monsoons organized by The International Centre for Theoretical Sciences (ICTS), Bengaluru on 27th November 2024 for Students/ECRs.
- 6th Meteorological Week UFSM: Dr. Michelle Reboita (WG-AMM) delivered an online talk "Efeito das mudanças climáticas nos sistemas atmosféricos que atuam na América do Sul", on 21 Mar 2024 (https://www.youtube.com/watch?v=bUEWebWiQKc)
- EGU General Assembly 2024, European Geosciences Union, Vienna, 14-19 April 2024: Dr. Alice Grimm (WG-AMM) delivered the oral presentation "Towards robust and actionable information on monsoon climate change in South America. Abstract EGU24-13343, Oral Session AS1.18 – Monsoon systems in a changing climate: past, present and future.

- DHN - Marinha do Brasil: Michelle Reboita delivered a talk online with title: “Teleconexões e Previsão Sazonal do Clima”, on 20th September 2024 (Videoconferência sobre o tema Previsão Climática-20240920 1444-1.mp4)
- 15th International Meeting on Statistical Climatology (IMSC), 24-28 June 2024, Centre International de Conférences, Meteo-France: Dr. Iracema Cavalcanti (WG-AMM) presented the paper “Verification of extreme wet and dry cases in Brazil predicted by ECMWF S2S model”.
- Seminar “Extreme Weather Events and the Crisis in Rio Grande do Sul, Brazilian Intelligence Agency (ABIN), Curitiba, April 7th, 2024: Dr. Alice Grimm (WG-AMM) presented the invited talk: Extreme Weather Events and the Natural Disaster of May/2024 in Rio Grande do Sul.
- Involvement of WG-AMM members in the Pan-American Meteorology Conference (CPAM 2024), Sao Paulo, Brazil, 19-23 August 2024:
- Dr. Marcelo Barreiro delivered the invited talk “Variability and predictability of the South Atlantic Convergence Zone on subseasonal time scales”.
- Dr. Alice Grimm delivered the invited talk “The South American Monsoon: variability and prediction challenges” in session ST03 (Climate Variability and Influence on the Americas).
- Dr. Alice Grimm presented the paper “Selection of the best statistical distribution to compute the SPI (Standardized Precipitation Index) for determining precipitation extremes in basins contributing to hydroelectric plants of the Brazilian National Interconnected System (SIN)”.
- Dr. Iracema Cavalcanti presented the paper “Droughts in South America and associated processes during austral summer”.
- Dr. Michele Reboita delivered an invited talk in session ST08 (Climate Projections in the Americas)
- Dr. Michele Reboita presented the paper “Identificação de eventos secos e úmidos hidrológicos na região SAM-IPCC”.
- CPTEC-INMET-FUNCEME-CENSIPAM Climate Prediction meetings (Online): Dr. Felipe Marques (WG-AMM) has been participating in the monthly meetings.
- Workshop of the R&D&I Climate Change Program “Innovative Ideas to Transform Tomorrow”, Engie Brazil Energy S.A., Florianopolis, 9th September 2024: Dr. Alice Grimm (WG-AMM) delivered an invited lecture on “How can anthropogenic climate change affect monsoon rainfall in Brazil?”

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

- WG-AAM’s Subgroup activities will continue and aim to publish results of work from the past 1-2 years.
- Monsoon Processes and Teleconnections Subgroup:
- To start the joint research on teleconnections between the Arctic Sea ice and East Asian cold extremes.
- To analyze the influences of cold surge on East and Southeast Asia with new cold surge features.
- To start joint research on monitoring and understanding heavy rainfall (including typhoons) over Southeast Asia and Northwestern Pacific.
- Research-to-operations for monsoon seasons in SE Asia Subgroup:
- To handle post-submission reviews and present the paper, “Introduction of Wind-based SEA Monsoon Index”
- To write up and submit the paper, “SEA Monsoon Characterization using wind-based SEA Monsoon Index”
- To disseminate and collect feedback on our SEA Monsoon Index in ASEANCOF in 2025. A separate webinar may subsequently be organised to involve operational forecasters on the use of SEA Monsoon Index.

- To verify the skill of our SEA Monsoon Index regarding monsoon seasons' onset, peak, termination and strength.
- To explore the use of SEA Monsoon Index to analyse changes in the region's monsoon under climate change scenarios using SingV3 8-km outputs from Meteorological Service Singapore.
- High-impact weather event Subgroup:
- Completion of the weather warning paper draft, followed by feedback from the larger AAMWG and then submission.
- Possible development of a second paper focusing on one particular case (e.g., of a tropical cyclone with compound flood/wind hazards) that affected multiple countries. This will compare forecasts and warnings issued by, and actions taken by, the affected NHMSs. A potential target is Typhoon Yagi.
- Four WG-AAM members will participate in-person in the IWM-8 during 17-21 March 2025 and present the following papers:
- "Asian Summer Monsoon Variability during 2022–2023: Beyond Canonical Teleconnection Patterns" submitted on behalf of the WG-AAM will be presented as an Oral Talk by Thea Turkington
- "Southeast Asian Monsoon Index for Its Monitoring and Prediction" submitted on behalf of R2O subgroup of WG-AAM will be presented as an Oral Talk by Thea Turkington
- "Using regional relaxation experiments to understand the development of errors in the Asian Summer Monsoon" will be presented as an Oral talk by Gill Martin.
- "Cloud and Convection Patterns Driven by Diurnal Ocean Warming" will be presented as an Oral Talk by Maheswar Pradhan.
- Three WG-AFM members will participate in-person in the IWM-8 during 17-21 March 2025 and present the following papers:
- "Investigating the Drivers of Dry Season Rainfall over Eastern Africa" will be presented as a poster by Caroline Wainwright
- "Southern African Monsoon: climatology and combined effect of SST interannual variability modes" will be presented as a poster by Kenedy C. Silverio
- "Model uncertainty in future changes in West African precipitation: component replication" will be presented as an Oral talk by Paul-Arthur Monerie.
- Three members of MP (Suryachandra Rao A., Annalisa Cherchi and Satyaban Ratna) will participate in the IWM-8 during 17-21 March 2025 and deliver the Invited/Oral talks.

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

- Monsoons Panel (MP) & 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 CDAS and 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

- 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 (Land Surface for Predictions) project of GEWEX/GASS and trying to see how to use land surface to predict extreme events over control regions.

e. Application

- MP & 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 continue its promotion of Research to Operations (R2O) activities with an aim to contribute to the Regional Climate Outlook Forums (RCOFs) and operational meteorological services.

g. Capacity Building

- WG-AFM organized the Joint WCRP/ WWRP Webinar Series on African Monsoons, held online on 6th March 2024, which featured talks by Prof. Michela Biasutti (Climate Change in the Sahel: The Past and the Future) and Dr. Samson Hagos (Synchronization of the Recent Decline of East African Long Rains and Northwestern Asian Warming). Out of the 138 registered attendees, 74 attended the webinar. Video recording of the webinar has been made available in IITM YouTube channel for wider reach & publicity, which has 240 views till date.
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- Michelle Reboita (WG-AMM) is a coordinator of "Environmental Connection", a radio program in FM band to discuss environmental topics. The programs are recorded - one example: https://conexaoitajuba.com.br/defesa-civil-alerta-para-possibilidade-de-fortes-chuvas-em-itajuba-e-regiao/
- 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.

Contributions to the GEWEX cience Goals and 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. (iv) do 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?

Other Key Science Questions

…

Contributions to WCRP including the WCRP Light House Activities

- Activities of MP & 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) was actively involved in the "My Climate Risk" LHA.
- Izidine Pinto (WG-AFM) was actively involved in "Safe Landing Climates" LHA.
- Annalisa Cherchi (MP) was a member of GPEX Interim SSC.

- Most members of the eastern Africa subgroup of WG-AFM were involved in EPESC LHA's "Africa Case Study" focusing on modeling the Eastern African rainfall.

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

- Dr. Satyaban Ratna (MP Member) as a member of CLIVAR Climate Dynamics Panel (CDP) and CLIVAR Pacific Atmospheric Teleconnections in a wArming Climate (PATAC) working Group, contributed to monsoon discussions.
- Wei Ting Chen and Lin Wang of WG-AAM joined the APARC activity on Atmospheric Composition and the Asian Summer Monsoon (ACAM).
- Dr. Lin Wang participated in the 33rd APARC SSG meeting at Forschungszentrum Jülich, Germany on 28th October and presented on "Collaboration Potentials between APARC/ACAM & CLIVAR/GEWEX Monsoons Panel".
- Following the recommendations of the CLIVAR SSG for MP's involvement in Quantitative evaluation of the Indian Ocean Observing System to improve climate forecasts (QIndOOS), a cross-panel discussion meeting was held on June 12, 2024, with Elisabeth Remy from the SynObs Project's Observing System Evaluation Task Team and Dr. Suryachandra A. Rao (MP) to evaluate the Ocean Observing System. Under this cross-panel activity with the impact of different ocean observations on model simulations, particularly of Asian monsoon and Indian monsoon is being examined.
- Drs. Hui Su and Hiroshi Takahashi of MP are collaborating with CliC on understanding the connections between the Himalayan cryosphere and Asian monsoons & Impacts of reduced Arctic sea-ice on Asian monsoons.
- Drs. Michelle Reboita, Parthasarathi Mukhopadhyay and Hatsuki Fujinami are members of WWRP/WGTMR (Working Group on Tropical Meteorology Research).
- Dr Joseph Basconcillo of WG-AAM has volunteered for GPEX LHA.
- WG-AFM is co-designing the Africa case study with the EPESC lighthouse activity.
- Masilin Gudoshava (WG-AFM) is involved in the "My Climate Risk" lighthouse activity and Izidine Pinto in "Safe Landing Climates."
- 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
- Annalisa Cherchi (MP) contributed to cross-panel activities as member of the SSG (interim) of GPEX.
- 3 MP members (Drs. Annalisa Cherchi, Hui Su and Samson Hagos) participated in GPEX meeting held in Washington DC during 6-7 December 2024. From 1st January 2025, they are effective members of GPEX with Dr. Annalisa Cherchi as GPEX Co-chair, Dr. Hui Su as Co-chair of WG2 (Data development) and Dr. Samson Hagos as Co-chair of WG1 (Coordinated field campaigns).
- On an invitation from CLIVAR/ IOC-GOOS Indian Ocean Regional Panel (IORP), Suryachandra Rao (MP) made a presentation on the skill of the models in predicting Asian monsoon, especially Indian summer monsoon. As a follow-up IORP and WG-AAM will work together to create a document suggesting the future requirements to improve the monsoon prediction skill. Maheswar Pradhan (new Member WG-AAM) will also be associated in it.

Workshops and Meetings

List of Workshops and Meetings held in 2024

- The Sixth Session of CLIVAR/GEWEX Monsoons Panel was held on 11th July 2024 during the 9th GEWEX/OSC at Sapporo, Japan in hybrid mode (with 4 members attending in-person and 4 online).

- A special hybrid meeting of MP and WG-AAM members (with 5 members attending in-person and 7 online) was also organized on 11th July 2024
- In addition, MP held 5 virtual meetings in 2024 (on 23rd January 4th April 10th June 13th September and 12th November), which enabled discussions on the cross-panel activities, 2025 Membership updates, activities of regional WGs and future work plans.
- A special meeting between the Monsoons Panel (MP) and the Working Group on American Monsoons (WG-AMM) was also held on 20th February 2024 to understand the issues faces by the working group.
- WG-AFM held 3 virtual meetings in 2024 (29th February 30th April and 26th November) to discuss on the writing of a review article on "Climate Modeling of Precipitation over Africa", the activities of their 3 sub-groups (Viz., South & East Africa, West Africa, and Central Africa) and 2025 Membership revisions.
- WG-AAM held 4 virtual meetings (on 15th January 2nd May 12th September and 21st November) to discuss on the activities of the group and its 3 sub-groups (Viz., Monsoon Processes and Teleconnections; R2O for monsoon seasons in SE Asia; High Impact Weather Events), 2025 Membership updates and on the Asian/Australian (summer) Monsoon 2024.

List of Workshops and Meetings Planned in 2024 and 2025

- The Seventh Session of CLIVAR/GEWEX Monsoons Panel is planned during the Pan-CLIVAR meeting during 22-26 September 2025 at Bali, Indonesia. The anticipated travel support required from GEWEX is **$7500.**

Other Meetings attended on Behalf of GEWEX or Panel in 2024

- 28th South Asian Climate Outlook Forum (SASCOF-28): Dr. Suryachandra Rao (MP Co-chair) chaired the session on Seasonal Prediction of South Asian Summer Monsoon 2024: Global and Regional Perspectives on 29th April 2024 at Pune. Dr. Satyaban Ratna (MP Member) was one of the main organizers of SASCOF-28. In coordination with UK Met Office, Dr. Satyaban Ratna (MP Member) also organized a National Framework for Climate Services (NFCS) session for the South Asian country participants during SASCOF-28
- ASEANCOF: The first hybrid ASEANCOF was held in May 2024 in Lao PDR, with one R2O subgroup member attending in person and one online. Mention was made that the working group are progressing with the regional monsoon index, with plans to share at ASEANCOF sessions in 2025. Members will also be invited to attend the ASEANCOF-23 session in November 2024.
- APARC SSG meeting: The 33rd APARC SSG meeting was held in October 2024 in Germany. Dr. Lin Wang from WG attended the meeting on behalf of the Monsoons Panel, delivered a talk to introduce the Monsoons Panel and its activities, and sought potential cross-panel collaborations with the APARC community.
- Eight members of MP and Working Groups participated (online and In-person) in the Asian-Australian-African (AAA) Monsoons Programme International Workshop, organized by the Chinese Academy of Meteorological Sciences, China Meteorological Administration, Qingdao, China, on 19th November 2024. The workshop discussed on the Asian-Australian-African Monsoons Programme and members contributed with comments on the influence of the variability of the AAA monsoons via teleconnections. It was an interesting workshop as it allowed exchanges of information between experts from different monsoon systems that are interconnected. Drs. Alice Grimm (Co-chair. WG-AMM) and Ajayamohan Ravindran (MP Member) attended in person. Drs. Suryachandra Rao (MP Co-chair), Thea Tukington (MP/WG-AAM Member), Satyaban Bishoyi Ratna (MP Member), Rondrotiana Barimalala (MP/WG-AFM Member), Hiroshi Takahashi (MP Member) and Parthasarathi Mukhopadhyay (WG-AAM member) attended online.

Publications during Reporting Period

List of Key Publications

Akinsanola AA, Wenhaji CW, Barimalala R, Monerie P-A, Dixon RD, Tamoffo AT, Adeniyi MO, Ongoma V, Diallo I, Gudoshava M, Wainwright CM, James R, Silverio KC, Faye A, Nangombe S, Pokam MW, Vondou DA, Hart NCG, Izidine Pinto, Kilavi M, Samson Hagos, Rajagopal EN, Rupa Kumar Kolli, Joseph Susmitha, 2024: "Modeling of Precipitation over Africa: Progress, Challenges, and Prospects", Advances in Atmospheric Sciences. http://www.iapjournals.ac.cn/aas/article/doi/10.1007/s00376-024-4187-6.

Ajayamohan, R.S., Gill Martin, Thea Turkington, Hatsuki Fujinami, Joseph Basconcillo, H. Annamalai, Shiromani Jayawardena, Raghavendra Ashrit, Hiroshi Takahashi, and Tieh Yong Koh, on behalf of the CLIVAR/GEWEX Regional Working Group on Asian Australian Monsoons, 2024: “Asian Summer Monsoon Variability during 2022–2023: Beyond Canonical Teleconnection Patterns”, GEWEX Quarterly, Vol. 34, No. 3 Quarter 3, 2024.

Ankur Srivastava, Suryachandra A. Rao, Subimal Ghosh (2024). “Impact of river freshwater on subseasonal to seasonal variability in a climate model Research activities in Earth system modelling”. Working Group on Numerical Experimentation. WCRP Report No.12/2024. WMO, Geneva. https://wgne.net/bluebook/

Cavazos, T.; Bettolli, M.L.; Campbell, D.; Sánchez Rodríguez, R. A.; Mycoo, M.; Arias, P. A.; Rivera, J.; Reboita, M. S., Gulizia, C.; Hidalgo, H. G.; Alfaro, E. J.; Stephenson, T. S.; Sörensson, A. A.; Cerezo-Mota, R.; Castellanos, E.; Ley, D.; Mahon, R., 2024: Challenges for climate change adaptation in Latin America and the Caribbean region. Front. Clim. Vol.6. https://doi.org/10.3389/fclim.2024.1392033

Keane, R. J., Srivastava, Ankur, and Martin, G. M (2024): Development of Indian summer monsoon precipitation biases in two seasonal forecasting systems and their response to large-scale drivers, Weather and Climate Dynamics, https://doi.org/10.5194/egusphere-2023-2653.

Maheswar Pradhan, Ankur Srivastava, Suryachandra A. Rao (2024). “Soil Moisture Feedback over Wet vs. Arid Regions of India”. Working Group on Numerical Experimentation. WCRP Report No.12/2024. WMO, Geneva. https://wgne.net/bluebook/

P. M. Dhage, Ankur Srivastava, Suryachandra A. Rao, A. Soni, and M. Pradhan (2024). “Applicability of seasonal forecasts from dynamical models for reservoir management practices”, Mausam, vol. 75, no. 2, pp. 559–572, https://doi.org/10.54302/mausam.v75i2.6229.

Rao, V. B.; Bhargavi, V. S. L.; Rosa, M. B.; Reboita, M. S.; Grimm, A. M., 2024: A comparison of Indian and South American monsoon variability and likely causes. Theoretical and Applied Climatology, Vol. 155, 3505–3523 https://doi.org/10.1007/s00704-024-04870-5

2.5.1 MP Rapporteurs' Report

Panel: CLIVAR/GEWEX Monsoon Panel
Rapporteur(s): Xubin Zeng, Jan Polcher, Benjamin Lamptey

Adherence to GEWEX and Panel's objective(s)

We welcome very much the list of overall objectives and goals for individual Working Groups (WGs) provided in the report.

Panel activities are very relevant to GEWEX and Monsoon Panel's objectives. The primary activities have been: organizing workshops, conferences, and webinars; giving presentations; and invidiaul involvement of panel and Working Group (WG) members in publications related to Panel objectives. What is lacking: organizing activities (e.g., coordinated observations, process understanding, modeling, data analysis) involving scientists from different countries to address specific science objectives.

Achievement of annual goals for this reporting period

The Panel Goals include a list of five bullets. While progress has been made on "communications", "Capacity development", and to some extent, "Support Research to Operation", the progress is lacking on the science (i.e., "prediction skill improvement" and "Improving understanding").

Major accomplishments and results in reporting period

- Heavily involved in organizing the STIPMEX Workshop in 2024 and the WMO International Workshop on Monsoon (IWM-8) in 2025 and gave presentations
- involved in organizing the GEWEX OSC and the monsoon session and gave presentations in 2024
- WG-AFM played a key role in organizing two WCRP/WWRP Webinars on African Monsoons in March and April 2024
- individual involvement of panel and WG members in publications related to Panel objectives and in organizing sessions and giving presentations at various conferences and workshops.

Arisen or noted science issues

There is a lack of organized scientific activities (e.g., coordinated observations, process understanding, modeling, data analysis) involving scientists from different countries.

Emerging Science

None

Future plans

Re-organization of a Working Group

Recommendations to Panel

Last year it was proposed to enhance the interactions with the other GEWEX panels. We would like to reiterate this recommendation and suggest that a first target should be to link WG-AAM and AsiaPEX of GHP. Some procedure should be found to allow collaborations between these activities. Given the international nature of the Monsoon Panel, it should allow to enhance the observations in the region and bring more attention to the observational networks in the Monsoon panel.

The Monsoon panel should focus on advancing its overall objectives by initiating collaborations and starting new projects. This should take precedence over reporting on the papers published by panel members or the conferences which were attended by panel members. Do all the papers listed acknowledge the contribution of the GEWEX/CLIVAR Monsoon Panel?

The research to operation (R2O) activity does not seem to have advanced much in 2024. Only one result is proposed: one monsoon index has been developed. The list of new projects and activities still contain only things to be done and not accomplishments. Please ensure this activity reaches its conclusion in 2025.

All three WGs should take advantage of the km-scale global model simulations available now. It should allow to analyze in these higher resolutions how the representation of monsoons in our Earth system models has progressed through the increased resolution. This could be achieved with a hackathon which facilitates the access to the model output of these km-scale simulations. Technology exists today to allow the analysis of data on the servers holding these data sets.

The Monsoon panel could use the opportunity of the WCRP fellowship to engage with the hydrological community, as was recommended last year.

Considerations for SSG

None

Additional Remarks

None

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Annex 2 – Meeting Agenda

Monday 10 February 2025				
Time			**Panel Presentations - Overview and Plans**	**Presenter**
08:15	–	08:30	Welcome	
08:30	–	10:00	GLASS – Global Land-Atmosphere System Study	Nate CHANEY, Anne VERHOEF, Volker WULFMEYER
10:00	–	10:30	Break	
10:30	–	12:00	GASS – Global Atmospheric System Studies Panel	Shaocheng XIE, Sandrine BONY
12:00	–	13:30	Lunch	
13:30	–	15:00	GHP – GEWEX Hydroclimatology Panel	Alireza NAZEMI, Paola ARIAS,
15:00	–	15:30	Break	
15:30	–	17:00	CLIVAR/GEWEX Monsoon Panel	Leila CARVALHO

Tuesday 11 February 2025				
Time			**Panel Presentations continued & External Relations**	**Presenter**
09:00	–	10:30	GDAP – GEWEX Data and Analysis Panel	Hiro MASUNAGA, Tristan L'ECUYER
10:30	–	11:00	Break	
11:00	–	11:30	Core Project - RIfS – Regional Information for Socie	Luke HARRINGTON
11:30	–	12:00	Core Project - APARC – Atmospheric Processes Anc their Role in Climate	Martin JUNCKER
12:00	–	12:30	Discussion on do Safe Landing Climate exists for th Water Cycle	Jan POLCHER
12:30	–	14:00	Lunch	
14:00	–	14:30	GEWEX OSC Stakeholder Feedback	Hiroki Okachi
14:30	–	15:00	Activities Review	Xubin ZENG, Jan POLCHER
15:00	–	15:30	Break	
15:30	–	16:00	World Meteorological Organization (WMO) – WCR Secretariat	Hindumathi PALANISAMY
16:00	–	17:00	World Climate Research Programme (WCRP) – Joir Scientific Committee (JSC)	Hindumathi PALANISAMY
17:00	–	17:30	The State of the Global Water Resources	Jan POLCHER

Wednesday 12 February 2025				
Time			**External Relations continued**	**Presenter**
09:00	–	09:45	Core Project CLIC – Climate and Cryosphere + Own Research Topic	Lauren VARGO
09:45	–	10:30	Untangling the effects of climate change and land use	Rogier WESTERHOFF
10:30	–	11:00	Break	
11:00	–	12:00	Sea Level Rise and Our Changing Coast	Ian HAMLING (GNS)
12:00	–	14:00	Lunch	
14:00	–	21:30	Afternoon and Evening Team Building Program	

Thursday 13 February 2025				
Time			**External Relations continued, Agency Updates & GEWEX Strategic Planning**	**Presenter**
09:00	–	09:20	National Aeronautics and Space Administration (NASA)	Craig FERGUSON (Remote)
09:20	–	09:40	Japanese Aerospace Exploration Agency (JAXA)	Riko OKI, Tadahiro HAYASAKA (Remote)
09:40	–	10:00	European Space Agency (ESA)	Diego FERNANDEZ (Remote)
10:00		10:30	Break	
10:30	–	10:45	ECMWF	Richard Forbes
10:45	–	11:00	LHA - Digital Earth	Andrew GETTELMAN / Pierre Luigi VIDALE (Remote)
11:00	–	11:15	LHA - GPEX	Annalisa CHERCHI (Remote) / Adrian McDonald
11:15		11:30	LHA - Safe Landing Climates	Steve SHERWOOD (Remote)
11:30	–	11:45	Core Project - CLIVAR	Agnus SANTOSA (Remote)
11:45		12:00	Core Project - ESMO	Roland SEFERIAN (Remote)
12:00		12:15	Core Project - CORDEX	Silvina SOLMAN (Remote)
12:15	–	12:30	WWRP – World Weather Research Programme / INpRRAH	Celine Catoen-Gilbert
12:30	–	14:00	Lunch	
14:00	–	15:00	GEWEX Strategic Direction and Activities	Xubin ZENG, Jan POLCHER
			- Global Water Monitor	
15:00	–	15:30	Break	
15:30	–	16:00	Any Other Topics/Ambassadors/Awards	Jan POLCHER, Xubin ZENG
16:00	–	17:00	Ambassadors Corner	Andy PITMAN, Michael EK
17:00	–	17:30	International GEWEX Project Office Update	Peter VAN OEVELEN

Friday 14 February 2025				
Time			**Rapporteur Rapports**	**Presenter**
09:00	–	09:30	GASS – Global Atmospheric System Studies Panel	Ruby LEUNG, MH AHN, Gavin SCHMIDT
09:30	–	10:00	GDAP – GEWEX Data and Analysis Panel	Richard Forbes, Suzanne CREWELL, Maria PILES
10:00	–	10:30	Break	
10:30	–	11:00	GLASS – Global Land-Atmosphere System Study	Martin BEST, Li JIA, Manon SABOT
11:00	–	11:30	GHP – GEWEX Hydroclimatology Panel	Jason Evans, Camila Alvare Garreton
11:30	–	12:00	CLIVAR/GEWEX Monsoon Panel	Xubin ZENG, Jan POLCHER
12:00	–	12:30	Summary Action Items and Recommendations	Peter VAN OEVELEN
12:30	–	14:00	Lunch	
14:00	–	15:00	Wrap Up	Peter VAN OEVELEN, Xubin ZENG, Jan POLCHER

Annex 3 - Acronyms

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

World Climate Research Programme
wcrp-climate.org