WORLD METEOROLOGICAL ORGANIZATION

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International Science Council

WCRP World Climate Research Programme

34th A&B Sessions of the GEWEX Scientific Steering Group

3–5 May 2022 | Paris, France
26–27 July 2022 | Monterey, CA, USA

November 2022

WCRP Publication No.: 7/2022

Bibliographic information

This report should be cited as:

Van Oevelen, Peter J., et al., 2022: 34th A&B Sessions of the GEWEX Scientific Steering Group. WCRP Report 7/2022; World Climate Research Programme (WCRP): Online; 98 pp.

Contact information

All enquiries regarding this report should be directed to wcrp@wmo.int or:

World Climate Research Programme
c/o World Meteorological Organization
7 bis, Avenue de la Paix
Case Postale 2300
CH-1211 Geneva 2
Switzerland

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Authorship and publisher's notice

This report was authored by Global Energy and Water Exchanges (GEWEX) Project.

[1]GEWEX Panels:

GASS	Global Atmospheric System Studies Panel
GDAP	GEWEX Data and Analysis Panel
GHP	GEWEX Hydroclimatology Panel
GLASS	Global Land-Atmosphere System Studies Panel

The **G**lobal **E**nergy and **W**ater **Ex**changes (**GEWEX**) project is a core project of the World Climate Research Programme (WCRP) and is dedicated to understanding Earth's water cycle and energy fluxes at the surface and in the atmosphere. We are a network of scientists gathering information on and researching the global water and energy cycles, which will help to predict changes in the world's climate.

WCRP is co-sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the International Science Council (ISC). See www.wmo.int, www.ioc-unesco.org and council.science.

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Executive Summary

This report documents the proceedings of the 34th Session of the Global Energy and Water Exchanges (GEWEX) Scientific Steering Group (SSG), the annual meeting of scientists who guide the formation of GEWEX's scientific program as well as Chairs and Co-Chairs of the GEWEX Panels. This year's annual meeting was divided in two separate sessions: 1) GEWEX SSG-34A hosted by Centre National de la Recherche Scientifique/Laboratoire de Météorologie Dynamique, Institut Pierre Simon Laplace in Paris, France from 3–5 May 2022 and 2) GEWEX SSG-34B held at the Hyatt Regency in Monterey, CA, USA on 26 & 27 July 2022, which was organized in conjunction with the 3rd Pan-GASS and 2022 Pan-GEWEX meetings.

The attendees reviewed the progress of GEWEX and its four Panels for the year 2021 and part of 2022 and discussed the program's relevance today and tomorrow.

All four GEWEX Panels reported many activities in 2021 and 2022 despite the unprecedented circumstances brought about by the pandemic. Activities ranged from installing new Panel members and the startup of new projects and initiatives to the development and marketing of products and the organization of online meetings and workshops. Ongoing projects are advancing according to plan or have ended successfully. Working groups in all four Panels have published articles in major scientific journals, have articles under review at this time, or both. Discussions on how to proceed, what is lacking, other possible topics to explore and discussions on existing or possible obstacles resulted in new action items and recommendations.

In 2021 and 2022, the support required to meet the obligations and responsibilities of the International GEWEX Project Office (IGPO) was provided by George Mason University under the Center for Ocean-Land-Atmosphere Studies (COLA).

In anticipation of 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). The GEWEX Science Plan serves as the backbone of, and provides direction to, the revision of the GEWEX strategic plan and science questions for the coming years.

Contents

1. Introduction and Overview

This report summarizes the main developments in GEWEX during 2021 and part of 2022 together and includes the major items and recommendations from the two 34th Sessions of the GEWEX Scientific Steering Group (SSG-34A/B).

The GEWEX SSG-34A, hosted by Centre National de la Recherche Scientifique/Laboratoire de Météorologie Dynamique, Institut Pierre Simon Laplace, took place in Paris, France from 3 to 5 May 2022. The focus of this meeting was on:

- developments of the four GEWEX Panels over the past period and goals for the coming year
- discussions about the new GEWEX Science Plan and other strategy documents in anticipation of Phase IV (2023–2032) of GEWEX
- developments and collaboration with the Lighthouse Activities (LHAs) and the two new core programmes of the World Climate Research Programme (WCRP), Earth System Modelling and Observations (ESMO) and Regional Information for Society (RifS).
- planning and program of the upcoming 2022 Pan-GEWEX and GEWEX SSG-34B meetings in Monterey, CA, USA from 25 to 30 July 2022

The GEWEX SSG-34B took place in Monterey, CA, U.S.A., on 26 & 27 July 2022. Apart from short science presentations from each of the four GEWEX Panels and the GEWEX/ Climate Variability and Predictability Project (CLIVAR) Monsoon Panel, this meeting focused on GEWEX's activities in relation to its sponsors and international partners.
Furthermore, we thanked Graeme Stephens for his work as Co-Chair of the GEWEX SSG for eight years and presented the first two GEWEX Ambassadors, Dr. Michael Ek and Dr. Claudia Stubenrauch. Both Dr. Ek's study of land processes, boundary-layers (BL) and BL clouds related to Earth system modeling, among other things, and Dr. Stubenrauch's efforts including leading the GEWEX cloud assessment and GEWEX Upper Tropospheric Clouds and Convection Process Evaluation Study (UTCC PROES), have proved invaluable for the GEWEX community.
The distinction of GEWEX Ambassador has been introduced to honor colleagues who have made the international GEWEX program possible by contributing a significant amount of their time and energy and who can continue to promote GEWEX in the broadest sense.

Besides GEWEX SSG members and GEWEX Panel Co-Chairs, representatives from the National Centre for Space Studies (CNES), the European Centre for Medium-Range Weather Forecasts (ECMWF), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), US Global Change Research Program (USGCRP), WCRP and WCRP's core programs and working groups and the World Meteorology Organization (WMO) participated in the GEWEX SSG 34A/B meetings.
The complete list of participants of the GEWEX SSG 34A/B can be found in Annex 1 and the agendas of both meetings in Annex 2.

Major results, goals and plans of GEWEX and each of its four Panels are expanded on in §1.1. Panel activities range from installing new Panel members and the startup of new projects to ongoing projects, development and marketing of products and organizing meetings and workshops. The annual overall report of each Panel, which is based on the annual reports of the individual working groups within the Panel, is presented in §2. Each Panel was assigned two or three SSG members as

rapporteurs. The rapporteurs reported on the development and progress of the Panel. Their findings are described in a rapporteurs' report, shown in Annex 3.

GEWEX links to WCRP and WMO and their respective core projects and programs are presented in §1.2. The presentations of WMO focused on the transitions they are going through and gave insight into their new vision on hydrology and the WMO Research Board hydrology research strategy for the period 2022–2030.

WCRP's presentation concentrated on i) the progress of the implementation of the new WCRP structure including updates from WCRP's Core Projects, ii) the three newly formed Tiger Teams: Climate Intervention, WCRP Global Precipitation EXperiment (GPEX) and Cycles and Budgets, and iii) the WCRP Open Science Conference planned in Kigali, Rwanda in October 2023. Information about WCRP's Lighthouse Activities and their progress is covered in §1.4, together with a status update from the CLIVAR/GEWEX Monsoon Panel. A summary of the roundtable discussion on "How to increase engagement with WCRP" can also be found in §1.4

§1.3 gives a summary of the roundtable discussion with other GEWEX sponsors and partners centered around five questions and shows areas of interest where collaboration with GEWEX might be initiated or intensified.

1.1 GEWEX and GEWEX Panels: Overview of Results, Goals and Plans

This section gives an overview of major results, goals and plans of GEWEX and the GEWEX Panels. The major activities, results and plans of the individual GEWEX Panels are described in more detail in Section 2.0.

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 Steering Committee (JSC). The GEWEX SSG consists of two Co-Chairs and eight panel members, and ex-officio members from NASA, ESA, JAXA and 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 these three major research areas. In addition, there are several cross-cutting activities within GEWEX: PROcess Evaluation Studies (PROES) and the CLIVAR/GEWEX Monsoon Panel. GEWEX representatives also participate in the five newly formed WCRP Lighthouse Activities (LHAs) and support the various Regional Focal Point (RFP) groups.

In anticipation of Phase IV (2023–2032) of GEWEX, 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) and science goals for the coming years. The third phase of GEWEX (2013–2022) will be concluded with an article in the Bulletin of the American Meteorological Society (BAMS) "*The First 30 Years of GEWEX*", https://doi.org/10.1175/BAMS-D-22-0061.1 (see fig. 1).

Fig. 1: Professors Pierre Morel and Verner Suomi at the University of Wisconsin–Madison, 13 May 1994. Their earlier meeting in 1984 laid the foundation for GEWEX.

The International GEWEX Project Office (IGPO) facilitated and coordinated GEWEX research across the GEWEX studies, activities and products. IGPO overseed 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-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 2021, 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.

During the 2021 reporting period, the IGPO, in addition to its regular daily duties, meetings and activities, focused on:

- finding collaboration partners and expanding its network in Central Asia and Africa
- assisting with the promising start of two new projects, i) Floods, a GEWEX Hydroclimatology Panel (GHP) Cross Cut, and ii) Irrigation, a joint project of GHP and the Global Land-Atmosphere System Studies (GLASS) Panel
- supporting the initiating Regional Hydroclimate Project (RHP) Regional Hydroclimate Project (RHP) ANDEX with drafting its white book and moving towards becoming a full RHP
- supporting and advancing the GEWEX Land/Atmosphere Feedback Observatory (GLAFO) Project
- assisting in the organization and provided the aftermath of the Pan-GASS Meeting, which had been rescheduled from October 2021 to July 2022 due to travel restrictions that were still in place in 2021 because of COVID-19
- organized and provided the aftermath of the 2022 Pan-GEWEX meeting, a meeting where all four panels get together to facilitate interaction and collaboration and which takes place about every five years. In addition to the relevant Panel business, the 2022 Pan-GEWEX will be centered around four topics:
    1. Energy and water cycles at regional scale
        a. Covering natural and managed environments
        b. Quantifying the different fluxes and reservoirs (with error bars)
    2. In which regions will closure point to emerging processes Km-scale observation and modelling of the Earth system
        a. From current resolutions to km-scale: what are the structural changes
        b. Processes and reservoirs resolved at km-scales
        c. Confronting models and observations at high resolution
        d. Diurnal scales and extremes (gradients, patterns, and intensities?)
        e. Impact on biosphere and carbon cycle
    3. Mesoscale organisation of convection
        a. Impact on the mean and variability of water and energy fluxes
        b. Role of surface/atmosphere impact in organisation
    4. Impact on the mean and variability of water and energy fluxes
        a. Role of surface/atmosphere impact in organisation of convection
        b. Role for extremes

Each panel was asked to think about and present their views on the following aspects for each question:

- Opportunities for the panel and GEWEX as a whole:
  - Exploitation of current activities,
  - Propose a new activity which would gather community interest.
- Identify gaps in data and tools (in our portfolio)
- Which cross-GEWEX collaborations will be needed
- How will it contribute to the 3 GEWEX goals
- How does it link to the LHA and other core projects?

The **Global Atmospheric System Studies** (GASS) Panel 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 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.

The 3rd Pan-GASS meeting took place in Monterey, CA, USA from 25 to 29 July 2022. In addition to its regular program of oral and poster presentations and breakout groups, this successful meeting hosted three competitions for Early Careers Researchers (ECRs). Two ECR competitions were dedicated to stimulating the use of data sets from the DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains (DYAMOND) and the Atmospheric Radiation Measurement (ARM) program of the US Department of Energy. The third ECR competition, organized by WCRP and the GEWEX GASS Panel, covered poster and oral presentations competency.

Currently, GASS has four active and two affiliated projects. GASS projects are all related to the top three errors of the Working Group on Numerical Experimentation (WGNE) systematic error survey:

5. Convective precipitation—including diurnal cycle, intensity and frequency
6. Surface fluxes and temperature diurnal cycle
7. Cloud microphysics

GASS Projects

The objective of the Surface drag and momentum transport project: COnstraining ORographic Drag Effects (COORDE) is to understand the effects of resolved and parametrized orographic drag through the COORDE-nation of different modeling groups. Phase II of this project is completed and the paper is published in the *Journal of Advances in Modeling Earth Systems*. There is interest in continuing the collaboration in this group, with a possibility of COORDE-like experiments over the Rocky Mountains, gathering information about current and future model development on orographic drag from different collaborators.

The paper on the Demistify project, a Large Eddy Simulation (LES) and Numerical Weather Prediction (NWP) fog modeling intercomparison was published in the *Atmospheric Chemistry and Physics* in January 2022. There seems to be no more consistency for LES than for Single Column Models (SCMs), suggesting that microphysics and radiation are the key cause for the found variation, and not turbulence. A follow-up study is being discussed among the project members.

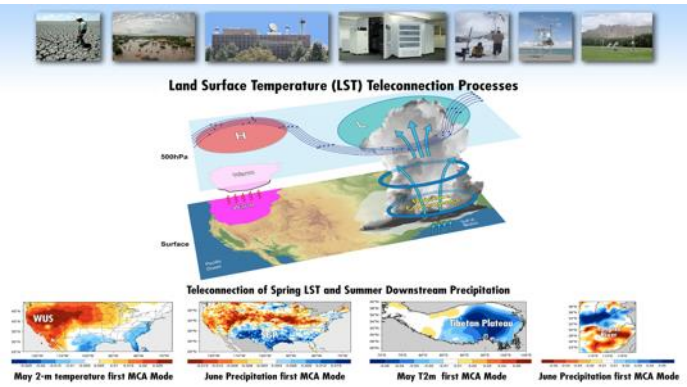

Fig. 2: Impact of Initialized Land Temperature and Snowpack on Sub-Seasonal to Seasonal Prediction Phase 1 (LS4P-I).

Phase I of the Impact of Initialized Land Temperature and Snowpack on Sub-Seasonal to Seasonal Prediction (LS4P) project is completed (Fig.2). Twenty modeling centers submitted their results and showed that high elevation land surface and subsurface temperatures in the Third Pole region have substantial predictive capability for precipitation on subseasonal to seasonal (S2S) timescales. The impact on precipitation anomalies is global. The paper on LS4P Phase I is published in the *Geoscientific Model Development Journal* while a BAMS article is under review.

The experiments in LS4P Phase II will concentrate on the Land Surface Temperature (LST) effect in the Rocky Mountains. Its Kickoff Workshop took place in the form of a side meeting at the American Geophysical Union (AGU) Fall Meeting in December 2022.

The Diurnal and Sub-Diurnal Precipitation project, which goal is to: i) understand what processes control the diurnal and sub-diurnal variation of precipitation over different climate regimes in observations and in models, and ii) identify the deficiencies and missing physics in current General Circulation Models (GCMs) to gain insights for further improving the parameterization of convection in GCMs. This project focuses on the US Great Plains and Amazonas. Multiple phases are ongoing, focusing on:

- interaction between convection and water vapor
- nocturnal convection over land
- diurnal cycle of convection over ocean
- convection transition

The first paper, Long-term single-column model intercomparison of diurnal cycle of precipitation over midlatitude and tropical land, was published in *the Quarterly Journal of the Royal Meteorological Society.*

The affiliated GEWEX Upper Tropospheric Clouds and Convection Process Evaluation Study (UTCC PROES) studies the relationship between convection and upper-tropospheric clouds and the role of cloud-radiative heating in convective organization and atmospheric circulation (Fig. 3). Advancement and next steps were discussed in one of the breakout groups at the 3rd Pan-GASS meeting. Datasets that are available include:

1) the Tracking Of Organized Convection through A three dimensional segmentatioN (TOOCAN) convective system, a cloud tracking algorithm to detect and track mesoscale convective systems from the geostationary infrared observations at https://toocan.ipsl.fr/, and
2) a 3-D description of upper tropospheric (UT) cloud systems using machine learning and Synergistic Satellite Observations [Atmospheric Infrared Sounder (AIRS) – CloudSat (a 94 GHz profiling radar) - Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO), AIRS-Tropical Rainfall Measuring Mission (TRMM), Infrared Atmospheric Sounding Interferometer (IASI) instrument - TRMM], which is in preparation.

The next step in this study will be to combine information from both datasets.

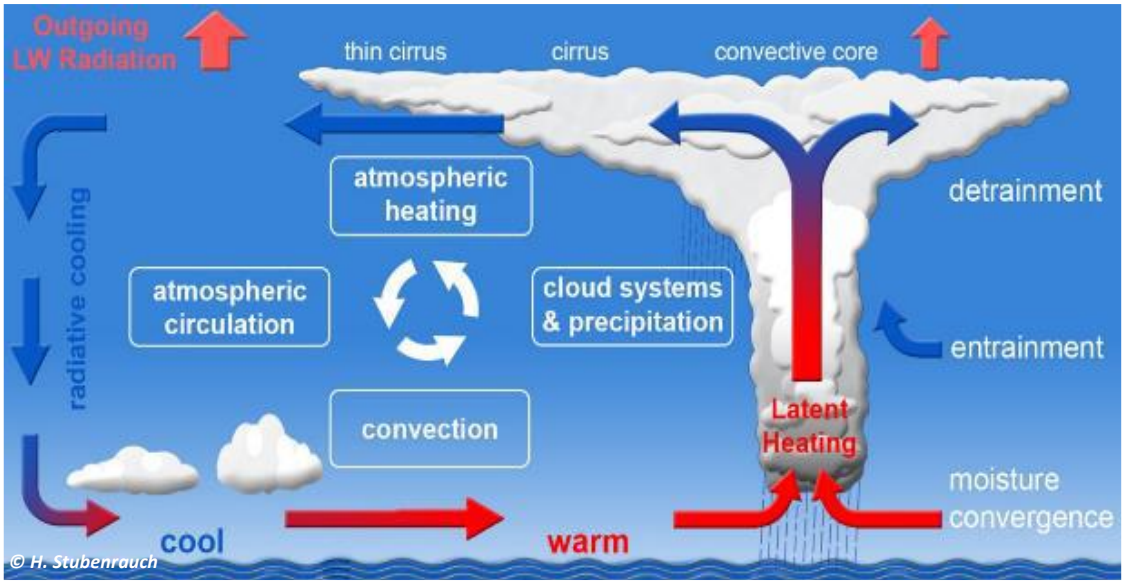

Fig. 3: Upper Tropospheric Clouds and Convection Process

The GEWEX Aerosol Precipitation initiative (GAP) is advancing at a steady pace. The intention is to integrate this project into GASS. One of the breakout groups at the 3rd Pan-GASS meeting was dedicated to this initiative to discuss the option of an intercomparison project with members of the community.

Opportunities for future GASS projects involve:

- Legacy of the WCRP Grand Challenge on Clouds, Circulation and Climate Sensitivity
  - role of cloud processes in extreme events, longwave scattering circulation, climate sensitivity?
  - convective organization/aggregation: physical mechanisms and role in climate?
- New observations
  - recent field campaigns e.g., Elucidating the Role of Clouds-Circulation Coupling in Climate (EUREC^{4}A), Cold-air Outbreaks in the Marine Boundary Layer Experiment (COMBLE), Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC), Field Experiment on sub mesoscale spatio-temporal variability in Lindenberg (FESSTVaL)
  - new satellite datasets e.g., long time series precipitation/radiation/clouds, high-resolution global Earth observations, Synthetic Aperture Radar (SAR), etc.
- New models
  - LES and Cloud-Resolving Modeling (CRM) running over larger and larger domains
  - new, emerging generation of climate models (global storm-resolving models)
- Cross-WCRP synergies and complementarities
  - GASS-Cloud Feedback Model Intercomparison Project (CFMIP) collaboration on cloud feedback processes to be re-activated
  - GASS-WGNE collaboration on model development
  - GASS-GDAP mutual interest in process diagnostics and observations

The following GASS Projects are planned:

- Mesoscale organization of shallow convection and trade wind cloud feedback processes:

analysis of EUREC^{4}A observations, evaluation of a hierarchy of models, implications for modeling and cloud feedbacks. This work will be done in collaboration with CFMIP, which is part of the Working Group on Coupled Modeling (WGCM), and WGNE.

- Organization of deep convection:
  understanding the underlying mechanisms and assessing the impact of convective organization in the model's behavior and performance. This work is to be done in collaboration with WGNE and CFMIP, and with the Digital Twins LHA. There are potential links to extremes and the World Weather Research Programme (WWRP).
- Air-sea coupling:
  role of the air-sea coupling on the local scale for shallow clouds and their organization and the effect of the local scale coupling on the large-scale circulation (i.e., the Intertropical Convergence Zone (ITCZ). This is a challenge for NWP and climate and a gap in WCRP. It exploits the atmospheric and oceanic parts of EUREC^{4}A and coupled storm- and eddy-resolving models.

GASS projects under consideration are:

- Arctic cold-air outbreaks (mesoscale organization, microphysics, COMBLE campaign:)
- Stable boundary layer as follow-up to the GEWEX Atmospheric Boundary Layer Study versions 3 and 4 (GABLS3/4GABLS3/4); e.g., around the MOSAiC campaign over the Arctic– under discussion
- Convective momentum transport: taking advantage of the EUREC4A campaign, COORDE follow-on project.
- Diurnal cycle of precipitation (DCP): simulation by the Climate Model Intercomparison Project phase 6 (CMIP6) models, which is planned as part of DCP. This work will be done in collaboration with scientists from the Program for Climate Model Diagnosis and Intercomparison (PCMDI).

In relation to the WCRP Lighthouse Activity "Digital Earth", the GASS Panel sees itself as the home of high-resolution (atmospheric) modeling. Process models (CRM and LES) were developed and used in the GEWEX Cloud System Study (GCSS), which later became the GASS Panel, to study key cloud systems. When the simulation domain is large enough, GASS can play a role in studies involving spontaneous mesoscale organization and new global simulations with storm-resolving resolutions. GASS wants to promote i) the analysis of simulations from the new, emerging global km-scale models, ii) the evaluation of process models and global km-scale models with observations of similar resolution and iii) studies focused on the role of the mesoscale in large-scale/climate phenomena.

In this reporting period, there was little change to the GASS Panel membership, with one new member and one member rotating off.

The **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 and worldwide, where observations are centric to its activities.
At the core of this are three GDAP initiatives: (1) The long-awaited and recently released GEWEX Integrated Product (IP); (2) several new integrated assessments (e.g., land energy-water flux/storage activity, such as land surface temperature, soil moisture, evapotranspiration, surface radiation, heat storage; (3) leadership in the cross-WCRP activity centered on understanding Earth's energy imbalance and its variability on seasonal to decadal timescales. Central to all goals are the NASA observing system capabilities past, present, and future. GDAP activities consist of supporting surface networks and conducting assessments and projects. Following the lead of the GEWEX SATM, GDAP is

moving to map its activities to specific science drivers. This is a work in progress and Table 1 summarizes just a few initial ideas of how this mapping looks for some of GDAP's ongoing projects.

GDAP Science Activities

Science Focus	Activity
Energy imbalance and climate sensitivity	EEI Assessment
Cloud dynamics and feedbacks	ISCCP-NG
Global land-atmosphere interactions	GEWEX IP and Ground Networks
Global energy and water cycle variability	Land closure assessment
Precipitation extremes	Precipitation Assessment

Table 1: GDAP science Activities

GDAP Projects

The GEWEX Integrated Product (IP), a product long in the making, supplied all energy and water cycle parameters from GEWEX-supported products and several ancillary fields at 1°, 3-hourly resolution, on an equal area grid, from 1998–2015. Due to technical problems, the products are not and will not be as integrated as initially planned. Continuation of this project will be determined at the next GDAP meeting in September 2022.

The GEWEX IP workshop originally planned to take place in Toledo, Spain, in 2019 has been postponed twice on account of COVID-19 and is now scheduled to take place in April 2023. In the context of the evaluation of climate data records related to water and energy fluxes, this GEWEX-sponsored workshop will attempt to make progress in one area by focusing on the consistency, closure, and the underlying processes from both a satellite and a land model perspective. The outcome of the workshop should lead to a letter to funding agencies advising them of potential new fruitful research related to integrated land surface-atmosphere process studies, a new cross-Panel GDAP-GLASS activity. The new activity will fill a long-desired need to better engage local field sites like ARM and the Baseline Surface Radiation Network (BSRN and others in GDAP regional and global assessments as well as bridge the local scales addressed by GLASS process studies and larger scales addressed by GDAP consistency studies.

The International Satellite Cloud Climatology Project–Next Generation (ISCCP-NG) is an advanced new product aimed at international coordination of common channels on modern geostationary satellites to support cloud science and take advantage of the next generation geostationary platforms. Efforts to date focus on generating calibrated, gridded Level-1 radiances (L1g) from the entire GEOring. Level-2 cloud, aerosol, radiative flux, and precipitation products are to follow.

GDAP Assessments

Collaboration between the International Precipitation Working Group (IPWG) and GDAP has resulted in the Precipitation Assessment released in June 2021 (Fig. 4). It embraces several new GDAP principles and best practices, e.g., address global and regional scales, publish results, link findings to research/science questions and share databases. All data and the database Frequent Rainfall Observations on GridS (FROGS) are released and open to the public.

Fig. 4: Precipitation Assessment

The GEWEX Water Vapor Assessment (G-VAP) phase II will relate how water vapor products from satellite, in situ and re-analysis do compare on some climatological time scale. Part of this assessment is to:

- assess quality of profile data records over stratocumulus regions using GPS Radio Occultation
- intercompare and analyze quality of upper tropospheric humidity (UTH) products
- compare free troposphere humidity in subsiding regions to GPS Radio Occultation focusing on the higher moments of the pedotransfer functions
- analyze short term variability in near-surface/PBL water vapor within Greenhouse Gases Observing Satellite (GOSAT) timeline
- compare against high quality ground-based and in-situ observations such as the Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN)
- assess consistency of reference observations.

A special issue titled Analysis of atmospheric water vapour observations and their uncertainties for climate applications (ACP/AMT/ESSD/HESS inter-journal SI) was jointly organized between *Atmospheric Chemistry and Physics, Atmospheric Measurement Techniques, Earth System Science Data*, and *Hydrology and Earth System Sciences*.

The third assessment relates to the Earth Energy Imbalance (EEI) and is a new activity in GDAP. The objective of this assessment is to:

- assess distinct methods for determining EEI and reconcile uncertainties
- quantify EEI variability and the factors that influence it
- determine the scales on which EEI and regional energy imbalances can be quantified e.g., on what scales can the top of atmosphere and surface fluxes and clouds measures be reconciled?
- explore potential of current EEI estimates to constrain climate sensitivity.

Currently, the project website has gone live at www.gewex-eei.org. Geodetic and radiation data have been collected while the collection of in-situ data is still in progress. The community workshop planned in 2022 has been postponed to early 2023 due to COVID-19.

GDAP Surface Networks

Ground-based networks remain a vital component of GDAP science. GDAP supports three surface networks, namely the World Radiation Monitoring Center-Baseline Surface Radiation Network (WRMC-BSRN), the International Soil Moisture Network (ISMN) and the Global Precipitation Climatology Centre (GPCC).

Communication with GPCC and ISMN has been minimal in the current reporting period.
GPCC reports to GHP, while with the successful transfer of ISMN operations from TU Vienna to its new host, the International Centre for Water Resources and Global Change (ICWRGC) located at the Federal Institute of Hydrology (BfG) in Germany, a new point of contact needs to be found. Another option is to establish a link between ISMN and the GLASS SoilWat project.

The objective of the WRMC-BSRN network (Fig. 5) is to provide observations of the best possible quality for short- and long-wave surface radiation fluxes with a high sampling rate. Surface radiation measurements are a critical reference for anchoring satellite remote sensing products (e.g., Surface Radiation Budget (SRB) and ISCCP), analyses, and modeling. Continuous, calibrated environmental and climate data records exist at several sites spanning a variety of regimes. It also provides input for intercomparing and assessing radiative transfer models, e.g., Radiation Transfer Intercomparison (RAMI). Some BSRN sites are capable of hosting multiple instruments fostering development of new

technology and methods. Best practices and quality control procedures ensure utility of measurements and uniformity across stations.

The 17th WRMC-BSRN Scientific Workshop took place in Ispra, Italy in June 2022. The program of the workshop included:

- tutorials of new data quality and processing software programs were given
- presentations on various quality control programs and methods; centralized tools and quality control flags will be used increasingly in the next few years
- uncertainty and data quality groups meet jointly to merge efforts as appropriate
- discussion about developing Network Common Data Form (NETCDF) format for BSRN files.

Additionally, three new stations received a pending status (Lampedusa, Italy, Valentia, Ireland and Andes East of Santiago, Chile), WRMC-BSRN has become a Global Climate Observing System (GCOS) affiliated network, and a new working group was formed which will make an inventory of current Albedo measurements.

Fig. 5 WRMC-BSRN Network

74 Stations
- **1** still in Candidate status (Terra Nova Bay Antarctica)
- **3** pending statuses (not shown in the map: Cyprus, Thailand, Indonesia)
- **9** inactive

12,200+ monthly files in the archive

The 2022 GDAP meeting took place in conjunction with the workshop "*Challenges in the understanding of the global water-energy cycle and its changes in response to greenhouse gases emissions*" at the International Space Science Institute (ISSI) in Bern, Switzerland, in September 2022.
At the panel meeting, three new panel members were introduced and one of the current co-chairs has rotated off. The incoming co-chair is one of GDAP's longtime members.

Topics and challenges that were addressed at the workshop and the GDAP meeting:

- Top of Atmosphere Radiation and Imbalance: provide estimates of the historical time variations of the climate feedback parameters to constraint the pattern effect
- Atmosphere: articulate deep convection in the equilibrium climate sensitivity (ECS) framework
- Surface: is precipitation consistent with radiation?
- Subsurface: can we expand the cloud radiative feedback framework to include the role ocean heat uptake and sea surface temperature (SST) patterns?
- Consistency and Closure: Can we derive from observations consistent trends of the global water-energy fluxes?

In addition, the following topics were also discussed during the Panel meeting

- Understanding and expanding GDAP's role in cross-cuts, PROES, etc.
- Positioning of GDAP with the WCRP core project Earth System Modelling and Observations (ESMO) and the proposed Global Precipitation Experiment (GPEX)
- GDAP's involvement in WCRP's working groups and Lighthouse Activities.

The science objective of the **GEWEX Hydroclimatology Panel** (GHP) is to understand and predict continental to local-scale hydroclimates for hydrologic applications. Addressing the water cycle at these scales allows us to better understand the many components of the system, from its physical to economic to social aspects. Within GHP there are four types of projects: Regional Hydroclimate Projects (RHPs), Crosscutting Projects (CCs), Global Data Centers (GDCs) and GHP Networks.

Regional Hydroclimate Projects (RHPs)

RHPs are generally large, regionally-focused multidisciplinary projects that aim to improve the understanding and prediction of that region's weather, climate, and hydrology.

Fig. 6: Baltic Sea region

The active RHP, Baltic Earth, a follow-up to the RHP BALTEX, which ran from 1992 to 2012, studies Earth system science in the Baltic Sea region. The Baltic Sea drainage basin covers about 20% of Europe, with roughly 85 million people living at the shores of the Baltic Sea. In the highly populated south, the temperate climate hosts intensive agriculture and industry while in the northern part, the landscape is boreal and rural (Fig. 6).

Participation in this RHP is based on scientific interest. The scope and activities depend on the voluntary contributions of its members. Apart from the annual Baltic Earth Conference and publications, Baltic Earth also organizes a Summer and Winter school yearly, which are jointly funded by Leibniz Institute for Baltic Sea Research Warnemünde (IOW) and Helmholtz-Zentrum Hereon. In 2012, Baltic Earth and the Helsinki Commission (HELCOM) jointly developed and published the Climate Change in the Baltic Sea 2021 Fact Sheet, as part of the flagship publication series of HELCOM, the Baltic Sea Environment Proceedings (BSEP).

The overarching goal of the second active RHP, Global Water Futures (GWF) is to deliver risk management solutions informed by leading-edge water science and supported by innovative decision-making tools and to manage water futures in Canada and other cold regions where global warming is changing landscapes, ecosystems, and the water environment. The GWF Indigenous Community Water Research Strategy of the four partnering institutions in GWF (Universities of Saskatchewan and Waterloo and Wilfrid Laurier and McMaster Universities), co-created in collaboration with the Indigenous community, aims to deliver the following outcomes and impacts:

1. Improved disaster warning
2. Predicting water futures
3. Adapting and managing risks

Three interrelated pillars of activity structure GWF to achieve those results. (Fig. 7):

Pillar 1: Diagnosing and Predicting Change in Cold Regions
Pillar 2: Developing Big Data and Decision Support Systems
Pillar 3: Designing User Solutions,

New projects include research into climate projections, water-borne diseases, groundwater quality and quantity, lake ice, hydro-economics, metal release in thawing permafrost environments, inequitable impacts of water insecurity and more.

Fig. 7: GWF pillars of activity

The general objective of the Asian Precipitation EXperiment (AsiaPEX) is to understand Asian land precipitation over diverse hydroclimatological conditions for improvement of predictions, disaster reduction and sustainable development. The six approaches to achieve these objectives are:

- Observation and estimation of variation and extremes in Asian land precipitation and important variables
- Understanding and prediction of variability of Asian monsoon from subseasonal to interdecadal time scales
- Coordinated observation and modeling initiatives
- Process studies of Asian land precipitation focusing on diverse land-atmosphere interactions
- High resolution land surface hydrological modeling and monitoring incorporating impacts of human water withdrawal, agriculture, vegetation, and cryosphere
- Detection and projection of the climate change impact on regional precipitation in the Asian monsoon region.

The review paper on AsiaPEX, “Detection and Projection of the Climate Change Impact on Regional Precipitation in the Asian Monsoon Region”, is a collaborative effort of more than 20 researchers and was submitted to BAMS. The AsiaPEX science plan is expected to be submitted for review by GHP members in the coming months.

The Third Pole Environment Water Sustainability (TPE-WS) project is a prospective RHP intending to explore water sustainability in the Third Pole environment. The group has submitted their science plan, which is now under review by the GHP members. The Third Pole area) covers nearly 5 million km^2. It is the youngest, highest, and largest plateau on Earth, with an environment similar to that of the North and South Pole. Changes to its environment affect more than 2 billion people in the region and downstream. Expanding westward from the Third Pole, the Pan-Third Pole region covers 20 million km2 and is the home of over 3 billion people (Fig. 8).

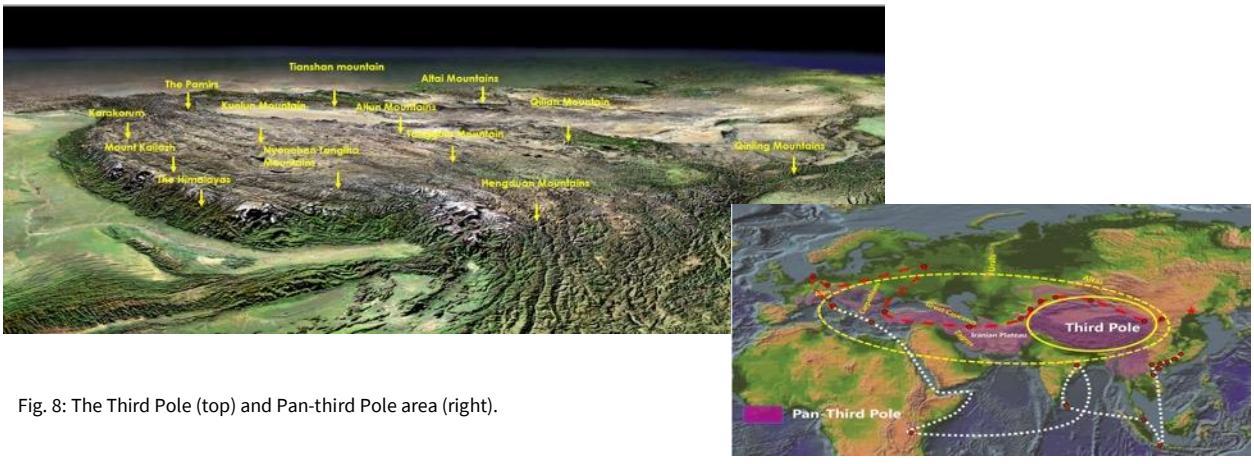

Fig. 8: The Third Pole (top) and Pan-third Pole area (right).

In 2021, TPE-WS continued with their many activities, for instance organizing sessions at the 2021 American and European Geosciences Union (AGU and EGU) and the Asia Oceania Geosciences Society (AOGS) meetings, publishing new data sets for many meteorological and environmental variables and setting up about 11 new Planetary Boundary Layer (PBL) towers and five new microwave radiometers for land-atmosphere interaction measurements.

As of March 2022, ANDEX officially became an initiating RHP. ANDEX focuses on the Andes Mountain range in South America and is in the process of organizing and uniting a relevant research community and obtaining international support. In the current reporting period, besides the annual ANDEX Meeting, a change of leadership has taken place and a webinar series jointly organized with the University of Antiqua and Pontifical Catholic University of Peru was launched. Each of the three webinars in 2022 was presented by two speakers and focused on a certain subject.

The US-RHP, "Water on the Edge in the Anthropocene", is another proposed RHP on the verge of applying for the initiating GEWEX RHP status. The US RHP Affinity Group consists of approximately 80 members. The group meets bi-weekly online, which starts with a technical/scientific presentation, including reflections on the nature of the RHP and ends with robust discussion on the presented topic. Thus far, four broad themes have emerged:

1. Closing the gap between models and observations
2. Improving our tools to understand and address a changing hydroclimate
3. Determining the energy and water budgets at the surface with greater fidelity in a rapidly changing world
4. Integrating the socio-economic and physical sciences (new)

After completion of the Hydrological cycle in the Mediterranean Experiment (HyMeX), a provisional international steering committee was formed to think about a follow-up to this successful RHP.
The goal of HyMeX phase II is to:

a. respond to societal and scientific challenges for the Mediterranean area and
b. establish and serve as a network/umbrella for former and new members.

A strong group of young researchers will lead the "new phase" of HyMeX, enlarging it to southern and Eastern countries and new communities. The next Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) Campaign was scheduled for the summer of 2021 with a focus on semi-arid surface processes and human influence on the water cycle.

Crosscutting Projects (CC)
Crosscutting projects are integral and focused activities within the GHP structures that address specific science questions and create collaborations between RHPs, other GEWEX Panels and WCRP activities.

Atmospheric processes specific to mountainous regions heavily affect the exchange of momentum, heat and mass between the Earth's surface and the atmosphere. The mulTi-scale transport and Exchange processes in the Atmosphere over Mountains – programme and eXperiment (TEAMx) CC is an international research program that aims at improving our understanding of these processes.

TEAMx objectives are to:

- improve understanding of transport and exchange processes both between the surface and atmosphere and at multiple scales within the atmosphere,

- provide a unique observational dataset,
- evaluate and improve the performance of weather and climate models over mountainous terrain, and
- reduce errors in impact models by transferring the knowledge gained to weather and climate service providers.

In May 2021, a second TEAMx workshop was organized with over 180 participants centered around TEAMx's plan for an observational campaign. Although TEAMx main focus is on the European Alps there are connections with their North American colleagues from INARCH in place. An overview of the motivation behind TEAMx and the aims of the programme was published in the GEWEX Quarterly (Nov. 2021, pg. 12–14) and Bulletin of the American Meteorological Society (BAMS) (https://doi.org/10.1175/BAMS-D-21-0232.1) in May 2022.

The International Network for Alpine Catchment Hydrology (INARCH) CC focuses on understanding hydrological processes in alpine cold regions. The outcome of INARCH Phase I, completed in 2020, is a suite of well-instrumented research basin, high-resolution forcing meteorological datasets, and advanced snowdrift-permitting and glacier-resolving hydrological models that are exemplars of Integrated High Mountain Observation and Prediction Systems (IHMOPS) (Fig. 9).

INARCH Phase II (2021–2026) needs to:

- provide common and archived observations for basin diagnosis and modeling through a Common Observation Period Experiment (COPE);
- enhance basin observations with novel and more sensors;
- Improve, downscale and correct atmospheric forcing datasets using basin observations;
- develop, improve, compare, and apply multiscale high-fidelity cryosphere-hydrological-water management models to river basins originating in high mountains
- work with communities 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;

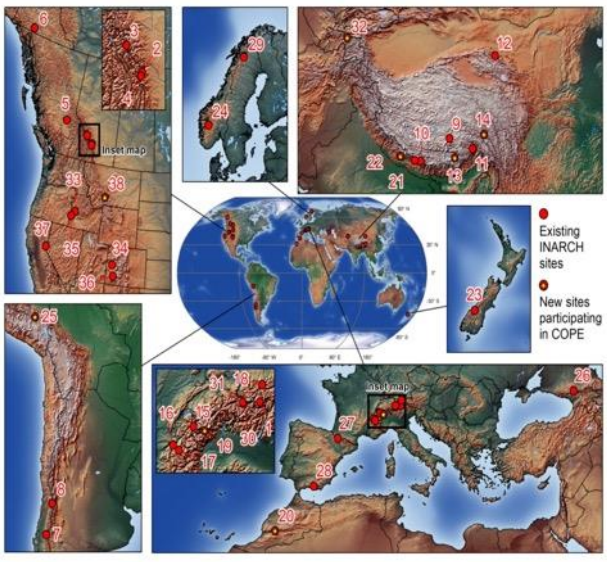

Fig. 9: Map of current INARCH mountain research basins.

- Austria 1. Rofental Open Air Laboratory (OpAL);
- Canada 2. Marmot Creek Research Basin; 3. Peyto Glacier; 4. Fortress Mountain Snow Observatory; 5. Quesnel River Research Basin; 6. Wolf Creek Research Basin;
- Chile 7. Valle Hermoso, Upper Diguillín River Basin; 8. Estero Las Bayas, Upper Maipo River Basin;
- China 9. Nam Co Monitoring and Research Station for Multisphere Interactions; 10. Qomolangma Atmospheric and Environmental Observation and Research Station; 11. Southeast Tibet Observation and Research Station for the Alpine Environment; 12. Upper Heihe River Basin; 13. Yala Shampo Cryosphere Hydro-Ecological Station*; 14. Changdu Ecological Monitoring Station*;
- France 15. Arve Catchement; 16. Col de Porte Experimental Site; 17. Col du Lac Blanc Experimental Site;
- Germany 18. Schneefernerhaus and Research Catchment;
- Italy 19. Torgnon Ecosystem Station*;
- Morrocco 20. Rheraya Catchment, High Atlas Mountains*;
- Nepal 21. Langtang Catchment; 22. Hidden Valley, Himalayas*
- New Zealand 23. Brewster Glacier;
- Norway 24. Finse Alpine Research Centre;
- Peru 25. Salcca-Sibinacocha Catchment*;
- Russia 26. Djankuat Research Basin;
- Spain 27. Izas Research Basin; 28. Guadalfeo Monitoring Network;
- Sweden 29. Tarfala Research Catchment;
- Switzerland 30. Dischma Research Catchment; 31. Weissfluhjoch Snow Study Site;
- Tajikistan 32. Kyzylsu Glacier and Monitoring Sites*;
- United States of America 33. Dry Creek Experimental Watershed; 34. Grand Mesa Study Site; 35. Reynolds Creek Experimental Watershed; 36. Senator Beck Basin Study Area; 37. Sagehen Creek, Sierra Nevada; 38. Bridger Range*.

with the objective to better:

- measure and understand high mountain atmospheric, hydrological, cryospheric, biological and human-water interaction processes,
- improve their prediction as coupled systems, and
- diagnose their sensitivities to climate change and propose how they may be managed to promote water sustainability under global change.

The proposal of the CC Determining Evapotranspiration (ET), an activity focusing on advancing the understanding and determination of evapotranspiration, is approved by GHP. Currently, the project members are in the process of adding the necessary expertise to the four working groups:

- WG1: Measuring ET and its role in the Surface Budgets (energy, water, carbon)
- WG2: Models and parameterizations of ET (including their use in numerical models and remote sensing methods), validation and networks
- WG3: ET from the different elements of the surface and partitioning: soil, vegetation, open water
- WG4: Heterogeneity, irrigation, varying spatial and temporal scales, extreme events.

It was also decided that data from the LIAISE experiment will be the subject of the first common effort of the CC- dET. A first LIAISE conference and Determining EvapoTranspiration (dET) CrossCut Workshop is being organized and is scheduled to take place in March 2023.

The proposed Irrigation CC is an initiative of the GEWEX GLASS and GHP Panels to advance understanding of the impacts of irrigation on the water and energy cycles and to better represent these effects in models. A successful virtual workshop was held in November 2021.

The opinion article on a proposed Flood CC in the *GEWEX Quarterly, Vol. 31, No. 4, Quarter 4, 2021* describes the GEWEX vision for a flood crosscutting initiative that should focus on overcoming barriers in designing appropriate modeling architectures to represent rapid rainfall-runoff processes and mechanisms within Earth system models across current and future flood-prone regions. A survey on this topic was sent to the appropriate group in the GEWEX community in 2021.

Global Data Centers

There are three Global Data Centers (GDCs) linked to GHP that collect and distribute important hydrology-related data: the Global Runoff Data Center (GRDC), the International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE) and the Global Precipitation Climatology Center (GPCC).

GPCC provides global precipitation analyses for monitoring and research of the Earth's climate. GPCC activities continue successfully with many new product releases. A change of leadership took place in 2022.

The GRDC is an international archive of data up to 200 years old and fosters multinational and global long-term hydrological studies. Originally established three decades ago, the aim of the GRDC is to help Earth scientists analyze global climate trends and assess environmental impacts and risks. With the implementation of an online Data Portal in June 2020, the number of data requests continue to increase.

The GRDC outlook for 2022 is to:

- Maintain data acquisition activities
- Extend and update data holdings
- Develop GRDC web applications for access to GRDC spatial products and database status
- Strengthen involvement in WMO hydrological activities
- Contribute to WMO expert teams and working groups
- Integrate next “GRDC generation”

HYDROLARE provides data on hydrology of world lakes and reservoirs. HYDROLARE was established in 2009 by Roshydromet at the State Hydrological Institute under the umbrella of WMO. Together with other hydrological data centers, it configures the Global Terrestrial Network-Hydrology (GTN-H; Fig. 10). It operates on the basis of free dissemination of information used for non-commercial purposes for governmental, scientific, educational, public, and commercial institutions. Contact with HYDROLARE is limited, and GHP is moving towards considering other possible data sources to fill the current gap in data availability and provide a sustainable data support to feed the envisioned activities, e.g., Irrigation, dET and Water Resource Management.

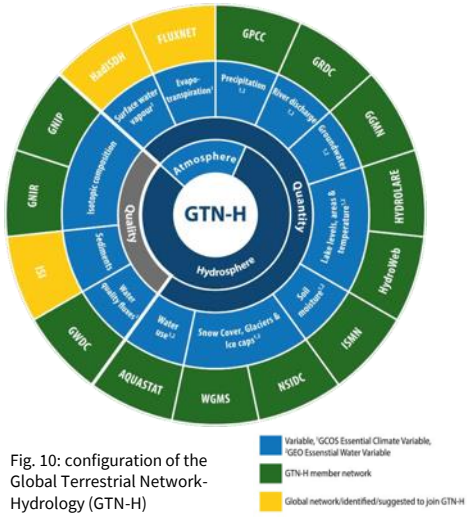

Fig. 10: configuration of the Global Terrestrial Network-Hydrology (GTN-H)

GHP Networks

GHP Networks are required to maintain collaboration and capacity building activities relevant to GEWEX science. Currently, there is one operational GHP Network, the Pannonian Basin Experiment (PannEx), a former initiating RHP Pannonian Basin Experiment (PannEx). PannEx focuses on the water and energy cycles in the Pannonian basin. A special issue on "Climate Extremes in the Pannonian Basin: Current Approaches and Challenges" was published in the journal *Atmosphere* in 2021. Additionally, in the summer, PannEX submitted a Cooperation in Science and Technology (COST) Action proposal to the CA20108 -FAIR NEtwork of micrometeorological measurements (FAIRNESS), which was accepted and is now in the preparatory phase.

Due to personal changes and leadership succession issues, the GHP Network OzEWEX, an Australian Energy and Water Exchange initiative, came to an end in December 2021.

The **Global Land/Atmosphere System Study** (GLASS) Panel’s objective is to improve the understanding of energy and water cycling on land and in the coupled land-atmosphere system and to improve representation of these processes in Earth system models. GLASS Panel membership has undergone major changes with nine members rotating off, and two new members coming in. GLASS is still looking for an expert on hydrology and human intervention in the climate system. GLASS activities center on facilitating and supporting international projects that use observations, process studies and numerical model experiments to develop and improve the representation of land and land-atmosphere systems in climate models. The primary emphasis of the GLASS projects is on three areas ranging from process to global scales: process insight, benchmarking and model comparisons. At present, GLASS has 10 projects, and is involved in two CC activities (Fig. 11).

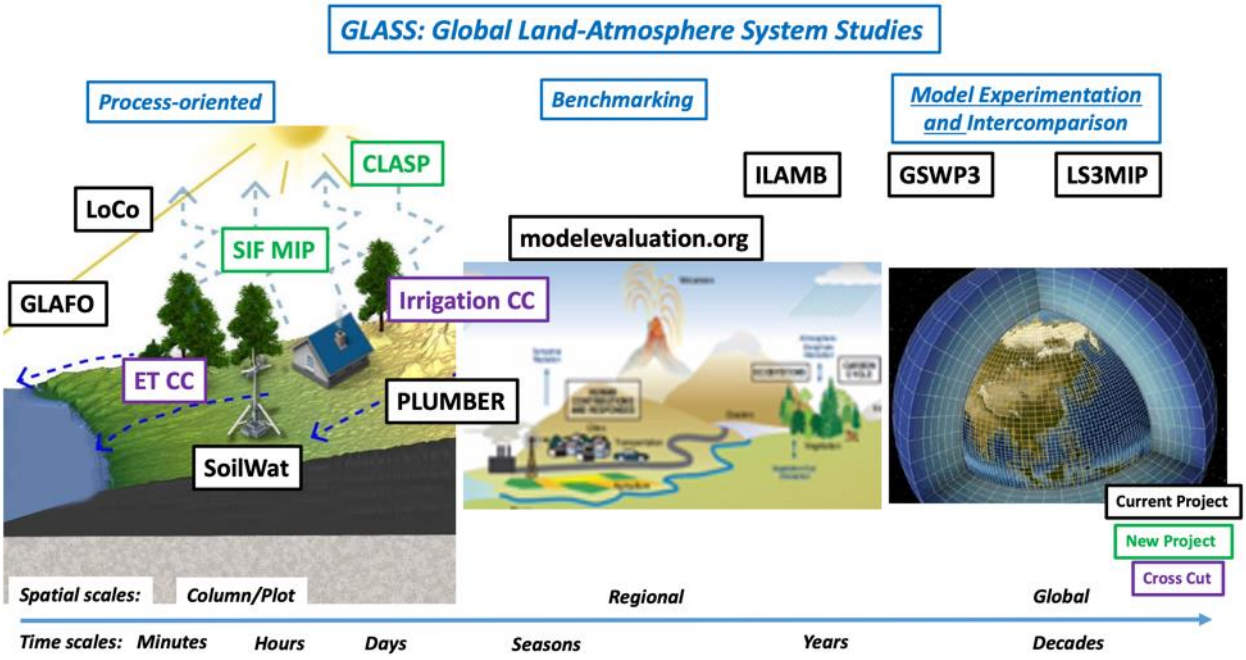

Fig. 11: GLASS projects and cross-cutting activities

Projects in the Process-Oriented Group:

- *Local Coupling Working Group* (LoCo), whose main objective is to understand, quantify, model and predict the role of local land-atmosphere coupling in the evolution of land-atmosphere fluxes and state variables and the respective water and energy cycles, including clouds. Some key achievements of LoCo are:
  - enhanced adoption of the LoCo paradigm at operational centers, use of LoCo metrics and diagnostics for integrative analysis, e.g., NOAA's Coupling of Land and Atmospheric Subgrid Parameterizations (CLASP) Climate Process Team and Unified Forecast System (UFS) development both stress LoCo process understanding
  - the NASA Planetary Boundary Layer (PBL) Study Team Report supports LoCo-inspired PBL incubation activities, and vision of monitoring PBL from space
  - Field campaigns (past and future) include LoCo-driven activities e.g., LIAISE in 2021
  - Enthusiasm for LoCo science seen in successful AGU and AMS sessions convened by LoCo WG members.

  LoCo has provided context and a framework from which to tackle the complex world of L-A coupling that did not previously exist at the time of the Global Land Atmospheric Coupling Experiment (GLACE). LoCo is explicitly (metrics, name recognition) and implicitly (soil moisture-precipitation chain) supporting the science contained in the many LoCo studies published each year. Its presence can be felt and is requested in community meetings, workshops, white papers and in funding calls and it has a place at the table in Global Climate Model (GCM) development now, including an opening with shorter

timescales (UFS). LoCo motivates the community to consider new aspects of L-A coupling (e.g., extending beyond the current LoCo paradigm) and ask new questions.

- *GEWEX/GLASS Land-Atmosphere Observatories* (GLAFO), modeled on the success of the Land Atmosphere Feedback Experiment (LAFE) campaign on the Southern Great Plains in August 2017, GLAFO makes the measurement of L-A feedback in heterogeneous terrain possible. It forms the basis of a new generation of international experiments and observatories (Wulfmeyer et al., *BAMS 2018*, *GEWEX Quarterly 2020*). The objectives of GLAFO are to:
  - understand and characterize L-A feedback with advanced metrics
  - develop and operate GLAFOs from groundwater to soil to land cover to the lower troposphere
  - study transport and exchange processes at the interfaces between the compartments
  - identify the role of vegetation with respect to L-A feedback
  - assess the processes and scales at which L-A feedback is sensitive to terrestrial hydrology
  - investigate scale interactions and from turbulent to micro- to land heterogeneity mesoscale processes on the strength of L-A feedback
- *Protocol for the Analysis of Land Surface Models (PALS) Land Surface Model Benchmarking Evaluation Project, phase 2* (PLUMBER2): see Benchmarking projects.
- *GEWEX Soil and Water Initiative* (SoilWat), which brings together two research communities to improve the representation of soil and subsurface processes in climate models. SoilWat is broadly organized around three Initiatives.
  1. To conduct an in-depth survey on how key soil physical processes and properties (related to water and heat flow) are represented in Land Surface Models (LSMs).
  2. A systematic assessment of the utility of resolved soil maps and sensitivity of climate models to improve the quality and resolution of soil maps: Soil Parameter Model Intercomparison Project (SP-MIP)
  3. A survey of how groundwater is implemented in climate models and define strategies for better incorporation of groundwater in climate models.

  Some key achievements are:
- recommendations regarding PedoTransfer Functions (PTFs):
  - results obtained provide guidelines for the selection of PTFs in large scale models
  - suitability of 13 PTFs was assessed in terms of Hydrus model performance based on numerical stability, time-integrated behavior of cumulative evapotranspiration fluxes, using thirty years (10988 days). The Rosetta, Wosten, and Toth PTFs seem to be the most robust PTFs for the Mualem van Genuchten Soil Hydraulic Parameters (SHPs) and the PTF of Cosby et al. (1984) for the Brooks Corey functions.
  - Based on findings, it is strongly recommended to harmonize the PTFs used in model inter-comparison studies to avoid artefacts originating from the choice of PTF rather than from different model structures.
- the first outputs of the Soil Parameter Model Intercomparison Project (SP-MIP), a global multi-model experiment, whose focus is to determine how the LS-model spread is related to uncertainties in soil hydraulic parameters. SP-MIP was set up to look at hydraulic parameters and water balance. However, results show that soil thermal regime is important too. Soil hydraulic properties will affect soil moisture characteristics, which affects soil temperature properties and soil temperatures in turn. This has implications for energy, water, and carbon balance (e.g., permafrost). Work from SoilWat in the near future will comprise:

- a re-run of the Weihermüller et al. runs with other models (e.g., detailed soil physical models such as the Simultaneous Transfer of Energy, Mass and Momentum in Unsaturated Soil model, or STEMMUS), and revisiting the model outputs for evaluating the effects on thermal regime
- work with land surface modelers to (1) show the value of harmonizing the PTFs used in their models and in MIPs to avoid artefacts originating from the choice of PTF rather than from different model structures and (2) develop process-based evaluation metrics linked in the context of prediction of soil fluxes and state variables
- a compilation of a dataset of globally-distributed soil thermal properties, ideally combined with hydraulic properties. The dataset would serve to support development and verification of models simulating thermal properties, by both existing and novel approaches.
- A new SoilWat initiative: Evaluation Metrics for Soil Processes

- *The DIurnal land/atmosphere Coupling Experiment and GEWEX Atmospheric Boundary Layer Study* (DICE/GABLS) has been dormant since 2018. Efforts were undertaken to rekindle this project. A white paper is being written.

Projects in the Benchmarking Group:

- *PLUMBER2* is a model intercomparison experiment for land surface models. The project is conducted within PALS benchmarking system. PALS is now Modelevaluation.org. Project objectives are to:
  - evaluate of multiple leading land surface and ecosystem models for water and carbon fluxes
  - provide forcing and evaluation datasets for a model intercomparison project for land surface models
  - provide meteorological variables to force models and flux variables for evaluation from the dataset collection of 170 flux tower sites (Published: Ukkola et al., *Earth System Science Data*, 2022), spanning multiple biomes and climate zones globally. The original data were derived from the FLUXNET2015, La Thuile and OzFlux collections.

  Project status and planned analyses:
  - participation is growing (Fig. 12)

    Click here for the Plumber2 Protocol
  - paper on Quality Control is forthcoming
  - Budyko curve departure analysis
  - diurnal hysteresis/phase lag
  - benchmarking momentum flux as well as heat fluxes
  - transfer entropy networks to identify process representation issues

Fig. 12: PLUMBER2 participation

  - improved “PLUMBER plots” as high level all / site / variable / metric overview
  - focus on empirical models defining good/bad performance; removes flux magnitude and site complexity as confounding variables
  - “conditional analysis”, e.g., water-use efficiency and evaporative fraction during dry-down events and, domain clustering (forcing only, forcing+model states) to identify conditions of poor simulation
- *PALS/modelevaluation.org* is a web-based platform for evaluating and benchmarking computational models.

- *The International Land Model Benchmarking* (ILAMB) aims to conduct a systematic analysis of simulation of land variables and surface climate. The objectives of this project are to:
  - integrate analysis of 30+ variables with 70+ global, regional, and site-level datasets
  - focus on 4 categories: ecosystem and carbon, hydrologic cycle, radiation and energy cycle, and forcings
  - graphics and scoring system (annual mean, bias, relative bias, root-mean-square error, seasonal cycle phase, spatial distribution, interannual variability, variable-to-variable).

  Next steps and development of ILAMB is aimed to enhance the utility in model development:
  - Diurnal cycle metrics (prototype has been developed)
  - Add metrics from literature (runoff sensitivity, seasonal albedo transition, snow insulation)
  - Land-atmosphere coupling metrics (Climate Process Teams or CPT)
  - Experimental manipulations (N-addition, rainfall exclusion, etc.)
  - Land use change metrics

The Model Intercomparison Projects (MIP):

- *Global Soil Wetness Project, phase 3* (GSWP3) is an ongoing terrestrial modeling activity that produces a long-term reanalysis and investigates the changes of the energy-water-carbon cycles through the 20th and 21st century. The project finalized and distributed the forcing data set.
- *Land Surface, Snow and Soil Moisture MIP* (LS3MIP) assesses the performance of current land surface modules of Earth system models and quantifies land surface feedbacks in a changing climate. Several groups completed "Land-hist" experiments. Land-future experiments are underway.
- *Land Use MIP* (LUMIP) focused on understanding the impact of land use and land use change on climate. The timeline of this project is tied to the 6th Climate MIP (CMIP6) and has largely been concluded. Three papers are in preparation on CMIP6 land-historical simulations that cover land, water and carbon balances; simulations of cold processes; and provide an overview.

New Projects and Initiatives:

- *Irrigation Effort,* a CC project between GHP and GLASS. The Irrigation Effort CC is a MIP to better understand where/when our models have predictive capabilities for irrigation. It aims to make progress on a narrowly focused and pressing irrigation topic and enhance communication among existing groups that may be working independently on related irrigation topics. A series of online meetings and a workshop have taken place which resulted in:
  - definition of the most pressing challenges that need to be addressed about the understanding of the irrigation's role in the Earth system and its modeling
  - identification of existing or future field campaigns, besides LIAISE and the Great Plains Irrigation Experiment (GRAINEX), on other irrigation climates across the globe
  - utility of available satellite data products for the detection of irrigation impacts, and
  - design and execution of a Model Intercomparison Project to advance our understanding of the predictive capabilities for irrigation of our models.
- *Coupling of Land and Atmospheric Subgrid Parameterizations (CLASP)*, whose objective is to parameterize the heterogeneous sub-grid exchange between the land and atmosphere and characterize its implications for surface climate, variability, and extremes (Fig. 13).

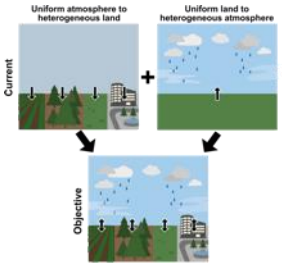

Fig. 13: CLASP Objective

The CLASP project aims to provide information about the role of role of sub-grid surface heterogeneity on atmospheric response, which has remained mostly ignored in practically all Earth system models. The emerging collaboration between CLASP and GLAFO helps define the GLAFO sites and observation needs while GLAFO observes the atmospheric boundary layer response to surface heterogeneity to inform CLASP efforts. Additionally, CLASP is motivating us to think more rigorously about the validity of Monin-Obukhov similarity theory for many heterogeneous landscapes. Long-term CLASP involvement in GLASS will help provide it with enough momentum to explore these "big-ticket" research questions in land-atmosphere interactions.

- *Solar-Induced Chlorophyll Fluorescence – MIP* (SIF-MIP) focuses on targeted assessments of simulations from an ensemble of process-based based terrestrial biosphere model (TBM)-SIF models, forced with local meteorology and analyzed against tower based continuous far-red SIF, net ecosystem production, gross primary product and energy exchanges. The basic protocol follows the Phase 1 SIF-MIP study using prescribed model inputs, designated model outputs, within model experiments (e.g., with/without data assimilation, different process representation). Phase 2 of SIF-MIP will expand the time and spatial scale of analysis, focusing on diurnal, synoptic, and seasonal variability at evergreen needleleaf (Old Black Spruce, Niwot Ridge, Delta Junction) and crop (Iowa corn and soybean) sites in North America.

  SIF-MIP ensures the presence of the coupling between the water and carbon cycles are represented in GLASS activities. Passive remote sensing of far-red SIF has spurred the development and integration of canopy-level fluorescence models in global terrestrial biosphere models (TBMs) for climate and carbon cycle research. It provides opportunities to diagnose and constrain model simulations of photosynthesis and related processes and provides direct comparison to and assimilation of tower, airborne, and satellite data.
- *SIF Benchmarking product*, a production of a carbon-water cycle reanalysis product which is to be submitted to the NASA program "Making Earth System Data Records for Use in Research Environments". The data record is a global gridded daily time series of coupled carbon-water surface fluxes (Net Ecosystem Exchanges, ET and component fluxes) derived from the CARbon DAta–MOdel fraMework (CARDAMOM), which assimilates satellite observational products into a simplified land surface model. Its uses include: (1) LSM benchmark, (2) observational constraint for data assimilation system, and (3) diagnostic of global carbon/water budgets and trends. This product links to ILAMB and the GDAP Integrated Product.
- With a new GLASS-GDAP liaison Panel member, conversations are underway about a number of possible initiatives, beginning with the utility of the GDAP Integrated Product for GLASS objectives

1.2 GEWEX Links to WMO, WCRP and WCRP Core Projects

Hydrological science is covered by two bodies within the United Nations Educational, Scientific and Cultural Organization (UNESCO):

1. the Intergovernmental Hydrological Programme (IHP) focused on research and showing a trend to move to water as a social good, and
2. WMO focused on hydrological forecasting.

In 2019, the WMO strategic plan 2020–2023 was published. Fig. 14 shows an overview of WMO's new vision on hydrology, including its mission, objectives and strategy for this period.

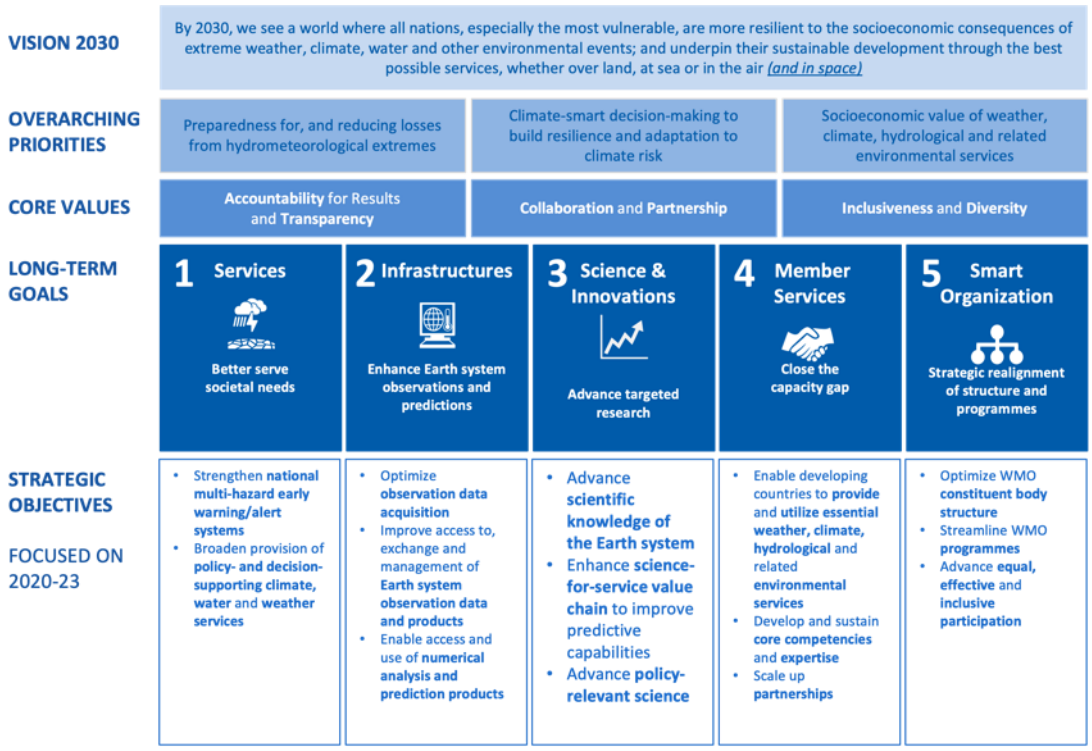

Fig. 14: WMO Strategic Plan 2020–2023 and its new vision on hydrology

The WMO Research Board in WMO translates the strategic aims of WMO and decisions of the Executive Council and Congress into overarching research priorities and ensures the implementation and coordination of the research programs to achieve the priorities set forth in the Strategic Plan 2020–2023. The Research Board has formed a Tiger Team to identify specific steps that can be taken to strengthen and prioritize the integration of hydrology into existing WMO programs [the Global Atmosphere Watch (GAW) Program, World Weather Research Program (WWRP), and WCRP] for greater societal and environmental benefits. The Research Board Hydrological Research Strategy 2022–2030, "Operational Hydrology Research Priorities and its implementation", is to be discussed in July 2022.

The Hydrological Coordination Panel (HCP) is WMO's think tank on hydrology. It supports and advises on an integrated delivery of WMO water-related activities, integrates the hydrological work of WMO into the wider global water agenda, and supports and advises the Executive Council Technical Coordination Committee. Furthermore, HCP promotes activities in operational hydrology and serves to further close cooperation between Meteorological and Hydrological Services.

The WMO Extraordinary Congress endorsed a Water Declaration, including the Water and Climate Coalition, in 2021. The coalition will work on establishing a Global Water Information System (GWIS) that will include the Global Hydrological Status and Outlook System (HydroSOS), a Global State of the Water Report, and a Global Water Data Portal.

Derived from the newly formulated vision on hydrology, WMO formulated eight ambitions in 2021 in its Action Plan for Hydrology:

- no one is surprised by a flood and people are prepared for drought
- hydroclimate and meteorological data support the food security agenda
- high-quality data supports science and science provides a sound basis for operational hydrology

- we have a thorough knowledge of the water resources of our world, including water quality; sustainable development is supported by hydrological information.

The main themes of the comments from the GEWEX SSG on this new WMO action plan are:

- Adopt an Earth system perspective to hydrological forecasting (i.e., coupled to other components).
- Consider explicitly climate change, land, and water usage in forecasting.
- Aim for a cooperation between research and operational forecast as it exists today for weather.
- Emphasize more open data sharing so that the research community can easily evaluate new data and forecasting tools.

Areas of interest and opportunities for GEWEX are:

- Spatial resolution & predictability:
  - Relevant to GASS and GLASS Panels
  - Contribution from GDAP for data to be used
- Land use & human influences:
  - Actions underway in GHP and GLASS Panel
- Hydrological early warning:
  - Could be a continuation of HydroSOS in collaboration with GHP and GLASS Panel
- Earth system modeling:
  - All GEWEX Panels

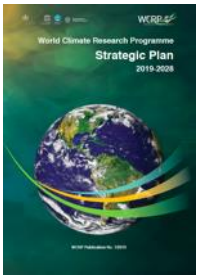

Fig. 15: WCRP Strategic Plan 2019–2028

The mission of WCRP is to coordinate and facilitate international climate research to develop, share and apply the climate knowledge that contributes to societal well-being (WCRP Strategic Plan 2019–2028; Fig. 15). Its four scientific objectives are the: i) fundamental understanding of the climate system, ii) prediction of the near-term evolution of the climate system, iii) long-term response of the climate system and iv) bridging climate and society.

The WCRP Science and Implementation Plan is a work in progress. Next steps include input from Core Projects (CPs) and Lighthouse Activities (LHAs). A first version has been distributed among the Joint Scientific Committee (JSC) for review.
New membership guidelines with information on gender and regional balance, and details on appointment and responsibilities of co-chairs, etc., has been submitted and is to be approved in the JSC-43 meeting in June 2022. With respect to the future budgets, CPs are asked to include less travel, e.g. plans or ideas for new ways of working, another model for virtual meetings, etc.

WCRP's new structure includes two new CPs, Earth System Modelling and Observations (ESMO) Regional Information for Society (RIfS), and WCRP Lighthouse Activities (see §1.4 GEWEX Outreach and Capacity-Building Activities).

Another work in progress is the organization of the WCRP Open Science Conference (OSC) 2023, *Advancing climate science of a sustainable future*, in Kigali, Rwanda from 23 to 27 October 2023. The OSC will be organized over five overarching themes:

1. Showcasing climate research achievements and advances; identifying science challenges and opportunities, including:
   - Climate processes, observations and modeling
   - Capacity development

2. Investigating drivers of climate change, impacts and risks, including extremes and rapid changes
3. Assessing risks to water, food and ecosystem and human health in a changing climate
4. Co-designing climate science that informs adaptation planning, with a focus on the near-term, regional information needed to address wellbeing, livelihoods and ecosystem health
5. Advancing the climate science and co-design needed for mitigation and sustainable development policies through co-design, including:
    - Socioeconomic scenarios and long-term climate projections
    - Climate intervention

To build interest and engagement, preparation of regional events around the globe prior to the OSC are underway; they are intended to develop science activities, e.g., regional contributions to a WCRP precipitation/water effort to be launched at the time of the conference.

New and emerging science issues are published in the sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR6). The world continues to see accelerating warming and associated impacts, such as weather and climate extremes. It will be a real challenge staying below a 2°C temperature increase. All scientific assessments seem to point to emissions continuing to grow, although not as fast as, e.g., Representative Concentration Pathway (RCP) 8.5. Particularly, the post-COVID era seems to have bounced back to pre-COVID emissions. Anthropogenic climate change, even 1.5°C warming, brings many significant challenges and risks that affect almost all aspects of life on Earth. Examples of what is already occurring and where amplified risks and impacts in the future will threaten millions of people around the world are droughts, heavy rain and flooding, heatwaves, extreme fire weather and coastal inundation. Risks will evolve further under progressively greater warming, and the extent of these impacts depends on our success in meeting our emissions targets. Climate information is needed at a regional level to allow action at the scale required for adaptation and understanding at the scale required to assess ecosystem and human impacts.

There are updates on three emerging additional topics within WCRP in the current reporting period:

1. *Climate Intervention*: A task team led by two JSC members has been formed to assess current research efforts in Carbon Dioxide Removal (CDR) and Solar Climate Intervention (SCI)—both internal and external to WCRP—and those in which it makes most sense for WCRP to engage. The aim is to determine the value WCRP could add to existing research efforts, as well as identify research gaps that WCRP could help fill and to identify partners, including other international research programs required for transdisciplinary research. Additionally, the task team is asked to determine how CDR and SCI research efforts best fit within the new WCRP organizational structure. Task Team recommendations will be made to the JSC-43 meeting.
2. *WCRP GPEX*: Over the past 20 years, slow improvement has been made in precipitation forecasts, although systematic errors exist, e.g., diurnal cycle of precipitation, sub-seasonal tropical variability, initiation of convective precipitation, etc. Similar systematic errors are seen in both weather and climate models. Agencies of United States Global Change Research Program (USGCRP), USGEWEX and USCLIVAR are interested in addressing key scientific gaps in precipitation prediction through the activity referred to as the Global Precipitation Experiment (GPEX). GPEX will systematically and comprehensively reduce model biases in global coupled models and improve precipitation prediction using an integrated observations and modeling strategy and targeting critical processes and phenomena (Fig. 16).

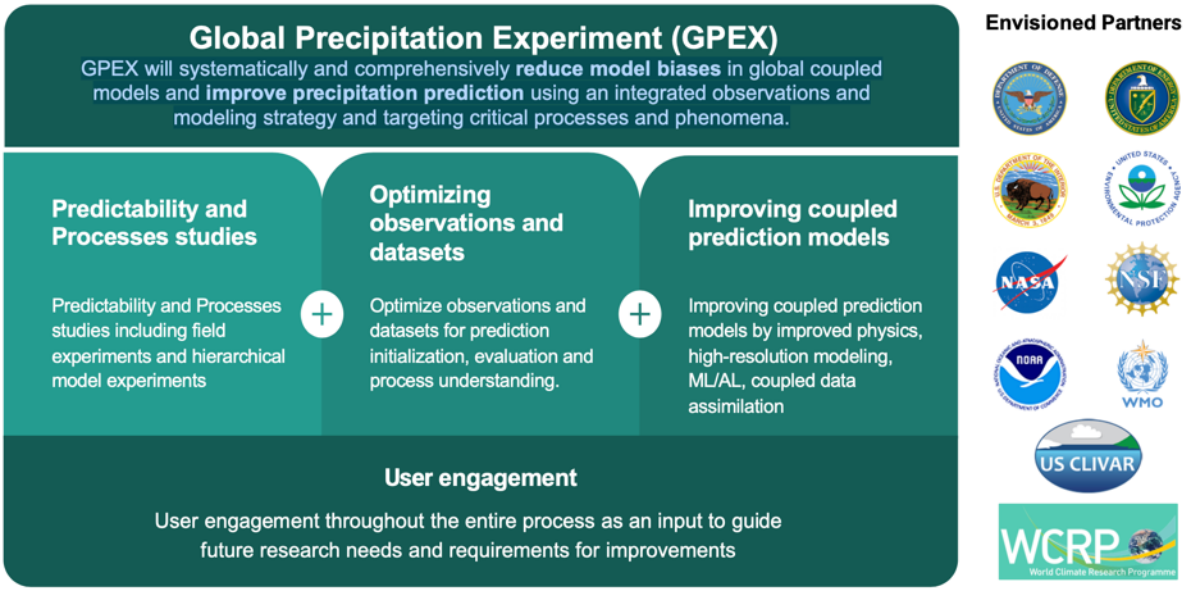

Fig. 16: The objective of the Global Precipitation Experiment (GPEX) and its envisioned partners

To ensure that GPEX becomes a truly global project, USGCRP has asked WCRP to take the lead in this initiative, which resulted in the formation of a Tiger Team led by one of GEWEX's co-chairs. This Tiger Team is charged with working out a strategy on how WCRP will address major science gaps in the field of precipitation. This strategy should include options for the best (effective and efficient) enabling structure within the WCRP to advance this research. The WCRP GPEX Tiger Team is of limited duration and operates on a fast time scale to produce a WCRP GPEX concept. The term of the Tiger Team ends at that point when the real activity is implemented.

3. *WCRP Cycles and Budgets*: A Task Team led by one of GEWEX's co-chairs has been formed to produce a strategy as to how research into the coupled energy, water and carbon cycles, across all time scales and across the land, atmosphere and ocean domains of the Earth system, can be best coordinated and facilitated as a cross-cutting theme across WCRP. As an example of such an effort, the Global Carbon Project (GCP) by the International Geosphere-Biosphere Programme (IGBP), part of FutureEarth, was mentioned. The Task Team's principal focus is within WCRP, identifying what WCRP can do. Input from external key partners such as GCOS and iLEAPS can be used as the strategy is being developed. This Task Team will also be of limited duration and will end once the strategy is being adopted by the JSC, ideally by the end of 2022.

   Fundamentally this closure study is an effort which is already underway in the community. The in 2019 Earth Energy Imbalance effort, jointly between GEWEX and CLIVAR, can be seen as a first step in this direction.

   Based on its expertise, GEWEX should take the lead in this effort. All previous closure studies done by the GEWEX community have:

   - shown limitations in either:
     - data availability or quality. Noted for fluxes and reservoirs and have led to large error bars
     - processes not properly taken into account and thus missing interactions or unmonitored boundary conditions
   - led to new process studies which have advanced our understanding

Cycle closure is an axiom for the community and serves to verify that our process knowledge and/or data are correct.

Evaluation within WCRP can determine whether the stage has been reached where monitoring of the cycles and budgets can be of more general use.

Next steps in this effort are to distribute a questionnaire among the GEWEX Panels and all relevant WCRP groups. Based on an evaluation of the response and a workshop organized to process all the information collected, conclusions can be drawn about opportunities and obstacles.

The core of WCRP research is organized into six enduring research communities, termed Core Projects (CP). Besides GEWEX, the other five WCRP core projects are: Climate and Cryosphere (CliC), Climate and Ocean Variability, Predictability and Change (CLIVAR), Earth System Modelling and Observations (ESMO), Regional Information for Climate (RIfS) and Stratosphere-troposphere Processes And their Role in Climate (SPARC).

The vision of *the Earth System Modelling and Observations* (ESMO) CP is to address overall coordination mechanism across all observations and model and data activities within WCRP.
ESMO is in the process of finalizing its science and implementation plan, which focuses on four overarching themes:

- *Research*: ESMO takes a seamless and value-chain model-data-observation approach across Earth system components, fundamental and applied disciplines, time and spatial scales. It will focus on coupled model systematic biases and development. This framework will enable the formulation of WCRP modeling and observational requirements to observe, understand and predict the climate system.
- *Infrastructure* will focus on integrated modeling and data infrastructures, and data policy, protocols and standards.
- *Access and Communication* describes how communication across WCRP constituencies, communities, partners and stakeholders will be addressed, including best practices of sharing data, knowledge and opportunities. Particular attention will be given to engagement, equal access and inclusion of the "global south".
- *Partnerships and Organization*: in this section stakeholders, scientific ambition and resourcing needs will be identified and fragmentation, duplications and suboptimal aspects in the program will be removed.

ESMO proposes a governance identical to the other WCRP core programs, including a Scientific Steering Group (SSG) which will be responsible for drawing up and implementing the program's science plan and its budget, and a project office to assist the SSG and affiliated working groups (Fig. 17). A call for a project office has been posted with a deadline for submitting proposals of July 31st, 2022.

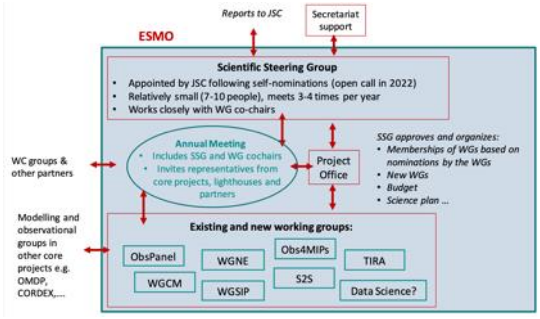

Fig. 17: WCRP's Core Project Earth System Modelling and Observations proposed governance

Priority of ESMO's science questions:

1. WCRP observational requirements and best practices to derive these requirements
2. systematic errors in observation data and observation systems
3. the future of climate modeling
4. sources and magnitude of systematic errors across time and space scales in Earth system models
5. use of variational methods, including data assimilation and sensitivity analysis, across timescales and in coupled systems
6. current and future changes in the carbon cycle.

The *Regional Information for Society* (RIfS) is a WCRP CP focused on research that underpins provision of actionable information for society's response to climate variability and change. The overarching

objective of this CP is to facilitate and catalyze new targeted research related to the provision of actionable information about climate variability and change in support of adaptation and mitigation that draws on the best available science. RIfS is organized around four inter-related and co-dependent clusters: i) Regional climate understanding for climate projections (multi-decadal), ii) Regional climate understanding for predictions (seasonal to decadal), iii) Weather and climate extremes, and iv) Communication and societal engagement. The RIfS Science Plan is finalized and is currently being reviewed by the JSC liaison before submission to the JSC for approval. After approval, a call for RIfS SSG membership will follow. WCRP has received two hosting and funding proposals for a new RIfS international project office. The decision about acceptance will take place in July 2022.

The vision of WCRP CP *Stratosphere-troposphere Processes And their Role in Climate* (SPARC) is to establish a comprehensive body of scientific knowledge on the role of the atmosphere in the global climate system with an emphasis on process understanding. Most SPARC activities are self-organized with ideas coming from the research community as new science questions arise and provide network opportunities centered on topical research. Currently, there are 15 SPARC activities. Through its activities, SPARC develops reports, e.g., SPARC Reanalysis Intercomparison Project (S-RIP) Final Report; contributes to assessment panels such as IPCC and the WMO/UNEP Ozone assessment; and builds capacity through involvement of early career researchers (ECRs) in activity leadership, organization of training schools and travel support to ECRs. SPARC has established collaborations with other communities e.g., other WCRP projects, WWRP (in particular with S2S), Global Atmosphere Watch, International Global Atmospheric Chemistry, and Future Earth.

SPARC's new structure includes three new partnership panels: i) Assessments Coordination Panel, ii) Partnerships Advisory Panel and iii) Outreach Advisory Panel. These Panels make it possible to include external representatives for other WCRP projects with whom SPARC wants to collaborate and engage and ensure that SPARC is, and stays, well connected with groups that have complementary focus areas.

The 7th SPARC General Assembly will take place in October 2022. This meeting will take place at three locations to lower the carbon footprint. This year's meeting will revolve around the following science themes:

- New ways of viewing the atmosphere through observations and re-analyses
- New understanding of atmospheric composition and variability
- Coupling between climate, radiation and dynamics
- How do dynamical processes shape climate variability and trends
- Climate prediction from sub-seasonal to decades
- Past and future of SPARC

Collaboration between SPARC and GEWEX includes the GEWEX Water Vapor Assessment, whose final report was published in 2017, the GEWEX/CLIVAR Monsoon Panel Atmospheric Composition and Asian Monsoon (ACAM) activity and SPARC representation on the GPEX Tiger Team. There are also several opportunities for collaboration between SPARC and GEWEX, e.g., the GASS crosscutting project on process understanding in the upper troposphere-lower stratosphere (UTTC PROES) and, as part of the new SPARC structure, new joint activities might be defined. Common research interests include cyclones, convection and high-resolution modeling. Another example of a possible joint activity is the SPARC project on sub-km processes in the atmosphere, which includes turbulence and gravity waves. This project can lead to a joint activity on high-resolution processes. Furthermore, looking at examples from the past, e.g., the SPARC-GEWEX-International Global Atmospheric Chemistry (IGAC) workshop in 2006

on “Modelling of Deep Convection and of Chemistry and their Roles in the Tropical Tropopause Layer”, common topics can be found that could be part of, or lead to, a workshop or webinar.

1.3 GEWEX Interactions with Sponsors and Partners

Discussion with space agencies and other related institutes has taken place in the form of a roundtable discussion and in the context of the aspirational vision of GEWEX since the beginning:
To measure and predict global and regional energy and water variations, trends and extremes, through improved observations and modeling; thereby providing the scientific underpinnings of climate services.

The discussion with representatives from CNES, Copernicus, ESA, EUMETSAT, JAXA, NASA and NOAA was initiated by the following questions:

- What should be the top priorities for space programs for the energy and water cycles and their coupling to the carbon cycle?
- What are your top priorities in Earth science space missions?
- What are the primary challenges in Earth science space missions?
- What are the major opportunities in Earth science space missions?
- What are the most important activities GEWEX can organize to help your agency’s program planning (e.g., future satellite missions)?

The main points to be taken from this discussion are the importance of maintaining operational, diverse and continuous observations and the continued need to develop dedicated instruments, e.g., rain radars, measurements of greenhouse gases from space, etc. Synergies between different observations will be key for the exploitation and use by the society to retrieve information relevant to the management of the environment. This requires transdisciplinary and inter-agency sharing and interoperability of datasets.

Priorities of Earth science space missions are related to re-analyses. The vast majority of users are users of re-analyses and not of satellite observations. Models are useful as a predictive element, and they also connect observations. This is fundamental, for example, for challenges such as measuring greenhouse gas emissions. For the long-term future and continuity of programs, it is important to provide anchor points, i.e., link to meteorological standards to quantify uncertainty. Models are required to invert observations into reliable estimates. This will only be possible if we have instruments with high accuracy. Another priority is to maintain the highest quality of data and follow through on accessibility and usability of data. The data user community is changing; it is no longer only communities like the GEWEX science community that belong to this group. The spectrum of users is becoming far more varied and include people that sometimes don’t even know they need the data or that they belong to the science community, for instance. Tools to access, understand and use data need to be developed and maintained.

Investment in re-analyses of the land surface is limited as it is more complex. Countries and research institutes should make this one of their priorities and contribute to this.

1.4 GEWEX Outreach and Capacity-Building Activities

The scope of the *International Climate Monsoon Project Office* (ICMPO) has been broadened to cover the monsoon research activities of both the WCRP and World Weather Research Programme (WWRP) through the establishment of a new International Monsoons Project

Office (IMPO) that continues to be hosted by the Indian Institute of Tropical Meteorology (IITM), Pune, India, under a new agreement signed between WMO and IITM.

The overarching goal of the GEWEX/CLIVAR Monsoons Panel is to advance understanding of monsoon variability and to improve its prediction with observations and modeling as the cornerstones of research activities. This goal is supported by four sub-objectives:

- enhanced emphasis on linkages across scales and physical processes;
- seeking new methods to enhance monitoring, advance diagnostics and improve models;
- development of more elaborated process studies coordinated with modeling activities, e.g., the Coupled Model Intercomparison Project Phase 6 (CMIP6);
- empowering the next generation of scientists around the world to advance our knowledge of monsoon systems, particularly in key regions of interest.

The GEWEX/CLIVAR Monsoons Panel is structured as a Monsoon Panel (MP) and three regional Working Groups (WGs), the Asian-Australian Monsoons (AAMWG), American Monsoons (AMMWG) and African Monsoons WG (AFMWG). Although each WG is dedicated to region-specific details, e.g., engaging with regional stakeholders and managing local knowledge exchange and up-skilling, all three are to provide authoritative information on processes understanding, models' fidelity in their (regional components) representations, forecast skill assessment and future projections of changes in monsoons under different radiative forcing scenarios.

The objective of AAMWG is to promote and facilitate collaborative research and training and support capacity building for early career scientists. AAMWG's key themes are:

- research-to-operations for monsoon seasons in SE Asia
- how well are high-impact weather events understood and forecast?
- monsoon teleconnections and processes in models.

Activities of AAMWG include developing the capacity of Southeast Asian countries to apply S2S forecasts and forecasting tools and participation in the South Asian and 15th session of the Association of Southeast Asian Nations Climate Outlook fora.

The objective of AMMWG is to promote and facilitate active engagement and interaction among research, operational predictions and stakeholders in the different regional monsoon components of the American Monsoon. AMMWG's key themes are:

- subseasonal-to-seasonal predictability of the American Monsoons,
- mechanisms and teleconnections driving monsoon variability on multiple temporal scales and their representation in models and
- present and future climate changes in the American Monsoons.

AFMWG formed three sub-groups focusing on a specific area: i) West Africa, ii) Central Africa and iii) East & South Africa. The AFMWG objective is to promote and facilitate research collaborations and conduct innovative African monsoon-related research. Key themes of this WG are:

- emphasis on sub-seasonal to seasonal prediction and climate change
- monsoons representation in climate models
- optimization of the use of operational seasonal prediction products, including Regional Climate Outlook Forums in Africa.

Throughout 2021, MP organized several well-attended teleconferences. These meetings were dedicated to updating their Terms of References and Work Plans and discussion regarding the status and progress of the WGs. WGs have been quite dormant in 2020/2021, which the MP is keen to address in 2022. MP initiated the Global Monsoons Model Intercomparison Project (GMMIP) which contributed to CMIP6 and IPCC's 6th Assessment Report.

During this reporting period, the MP supported the following workshops:

- The Seventh WMO International Workshop on the Monsoons (IWM-7) in collaboration with the World Weather Research Programme (WWRP), held during 23–26 March 2022, https://mausam.imd.gov.in/IWM7
- Online Training Workshop on Subseasonal to Seasonal (S2S) Prediction of Monsoons held in conjunction with and preceding the IWM-7 held during 1–12 November 2021, https://impo.tropmet.res.in/iwm7training.php
- Asian Oceania Geosciences Society Annual meeting: (2021 - virtual), session AS15: The Asian Monsoon in a Warming Environment

Interaction with WCRP's CP *Stratospheric Processes And their Role in Climate* (SPARC) is in development and focused on monsoons teleconnection dynamics, atmospheric composition and the Asian monsoon. SPARC Newsletter 59, published in July 2022, featured an article from the MP.
To further collaborations with GEWEX, MP is in discussion with GASS regarding the diurnal cycle project. MP is in discussion with CLIVAR regarding a cross-panel activity on ocean observations relevant to monsoon prediction. Additionally, MP contributed to the CLIVAR/ Intergovernmental Oceanographic Commission-Global Ocean Observing System (IOC-GOOS) Indian Ocean Region Panel (IORP) by developing research on Indian Ocean Observing Systems (IndOOS-2).

Examples of activities where MP can support and collaborate with LHAs:

- Explaining and Predicting Earth System Change (EPESC): process diagnostics and identification of sources of model errors in simulating monsoon precipitation.
- My Climate Risk (MCR): support work in cooperation with regional, national and multinational programs and improve regional weather forecasting, prediction of extreme events and their impacts.
- Digital Earths (DE): in association with IORP, MP is coming up with a report on the impact of observations from moored buoys on the prediction of South Asian Monsoon
- WCRP Academy: enhance capacities of researchers and students in monsoon-related topics by organizing or supporting training workshops and advanced schools, scientific congresses, sessions on monsoon themes, etc.

Planned and proposed meetings and workshops of MP and its WG for the coming period:

- AAMWG proposed a biennial symposium series, "Asian-Australian Monsoon: Linking Research to Operational Needs". Additionally, AAMWG will lead a session of the same title at the Asia Oceania Geosciences Society (AOGS) Annual Meeting 2022.
- AMMWG will organize: i) a special session on regional monsoons at the WCRP Open Science Conference on "Bridging Climate and Society" and ii) a second open training workshop on the South American Monsoon.
- AFMWG will host sessions at AGU/AMS/EGU and organize monsoon meetings and training workshops for students.

MP has insufficient funds to organize in-person workshops and meetings.

Planned and proposed activities of MP and its WG for the coming period:

- continued interaction with the IPCC AR6 and CMIP6 process, especially
- continued promotion of S2S diagnosis
- finalize plans for engagement with SPARC
- finalize plans for further engagement with GEWEX GLASS & GASS, in particular regarding land-surface interactions and projects
- explore possibilities of closely working with the Working Group on Seasonal to Interannual Prediction - Long-Range Forecast Monsoon (WGSIP-LRFM) project
- write review articles, e.g., a special issue of a Journal on African Monsoons, when financial support becomes available.

Activities associated with the WCRP Grand Challenges have mostly been sunsetted. As outlined in its Strategic Plan 2019–2028, WCRP has developed five new activities called *Lighthouse Activities* (LHAs). The LHAs are: Digital Earth (DE), Explaining and Predicting Earth System Change (EPESC), My Climate Risk (MCR), Safe Landing Climates (SLC) and WCRP Academy (Academy).

LHAs aim to make critical near-term progress towards meeting WCRP's Vision, Mission and four Scientific Objectives, as outlined in the WCRP Strategic Plan 2019–2028. They are designed to be ambitious and transdisciplinary (integrating across WCRP and collaborating with partners) so that they can rapidly advance some of the new science and technologies, and institutional frameworks, that are needed to manage climate risk and meet society's urgent need for robust and actionable climate information more effectively.

Digital Earths' goal is to support the establishment of integrated interactive digital information systems that provide global and regional information on the past, present and future of our planet and our human systems. It should provide a research framework to develop new capabilities across the globe and will require the creation of software infrastructures that are open, feely available, modular and interoperable. It will rely on a wide range of expertise that crosses multiple communities. What is most needed to get this done is:

- fully coupled km-scale regional and global models: need a global research network with expertise in km-scale modeling of the Earth system and its individual components. The goal is to define several demonstration projects converging diversity of regional foci, and regional-global dependencies and build scalable modeling and workflows that can facilitate transition from regional to global modeling and vice versa. The workshop "Modelling the Climate System at Ultra-High-Resolution" will be held in October 2022 in Boulder, CO, USA.
- Data assimilation for climate: establish an active research community in data assimilation for climate that builds on the existing numerical weather prediction and reanalysis efforts and significantly expands them. The goals are to extend data assimilation capabilities to climate prediction/projection in an operational framework, provide consistent and accurate descriptions of the past and present states of the Earth system and perform model testing and optimizations within a unified framework. The workshop "Data assimilation for climate" is planned for May 2022 in Boulder, CO, USA.
- Beyond the physical Earth system: include human interactions on and impacts to human systems in ESMs. The goal is to add new components to traditional Earth system models, all the way from detailed hydrological models to water and land management models to socio-economic impact models and establish a physical-impact science alliance that enables the co-design of physical Earth system approaches and that defines and implements success metrics in the use of Digital Earths

systems by society. Discussions with the GEWEX US RHP have started. There is a lot of interest; however, funding is not secured. Additionally, contact has been made with the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP).

The biggest challenges that LHA DE faces are:

- Global/regional km-scale modeling: communities are well established and do not see DE as value-adding.
- Data assimilation: there is no strongly organized community for building data assimilation systems for climate.
- Beyond the Physical System: two (at least) separate communities exist in vastly different orbits. Physical km-scale global models are still in development. Other model components are far from ready for integration.

Explaining and Predicting Earth System Change (EPESC)'s overarching objective is to design, and take major steps toward delivery of, an integrated capability for quantitative observation, explanation, early warning and prediction of Earth system change on global and regional scales and multi-annual to decadal timescales ("EPESC scales"). ESPESC's motivation is:

- The formulation of robust policies for mitigation of, and adaptation to, climate change requires quantitative understanding of how and why specific changes are unfolding in the Earth system.
- Quantitative process-based explanation (attribution) of observed changes is essential for quantifying current and future risks and fundamental to confidence in climate predictions and projections.
- Until very recently, attribution and prediction have been viewed as largely separate activities.

Changes in ocean and atmosphere circulation and their influence on hazards is a specific focus.

ESPESC has defined research questions for each of its three main themes/working groups (Fig. 18), which are:

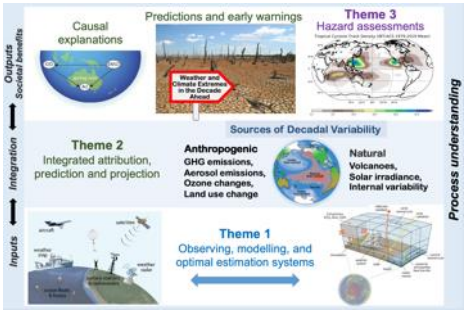

Fig. 18: Themes of LHA EPESC and their interaction.

I) Observing and Modelling Earth System

- What are the observational and modeling requirements to measure, explain and predict changes in the Earth system on EPESC scales?
- How can we most effectively combine observations and models to quantify, explain and predict changes in the Earth system on EPESC scales?
- How can we identify regions of the Earth where enhanced observations will offer the greatest improvements in predictive and explanatory skill?

Implementation priority is on data assimilation for climate.

II) Integrated Attribution, Prediction and Projection

- What are the observational and modeling requirements to measure, explain and predict changes in the Earth system on EPESC scales?
- How can we most effectively combine observations and models to quantify, explain and predict changes in the Earth system on EPESC scales?
- How can we identify regions of the Earth where enhanced observations will offer the greatest improvements in predictive and explanatory skill?

Implementation priority is on large ensemble single forcing experiments extended in real time to enable quasi-operational attribution and integrated attribution and prediction of water cycle changes.

It is advised to add a working group a representative to the Cycles Task Team led by GEWEX.

III) Assessment of current and future Hazards

- How do internal variability and external forcings influence the characteristics and occurrence of meteorological hazards on EPESC scales in different regions?
- How can we use observations, models and process understanding to deliver robust assessments of current and future hazards for specific regions and classes of hazard?

Implementation priority is on attribution and prediction of changing tropical cyclone risks. Crosscutting approaches and activities that will be developed are:

- Integrated use of observations and models
  - Characterization and quantification of uncertainties, which are fundamental to attribution
  - To what extent are models and observing systems adequate for the tasks?
- Case studies of significant changes and multi-annual-to-decadal events
  - Targeted research to quantify, explain and assess the predictability of carefully-selected recent events
  - Integrating insights of all three themes
- Large ensembles
  - Large ensemble single forcing experiments necessary for quantitative explanation of Earth system change
  - High resolution ensembles necessary to understand circulation change and modulation of hazards
  - Potential collaboration with LHA DE and/or WCRP core project ESMO.

In 2021/2022 the WCRP workshop on "Attribution of Multi-annual to Decadal Changes in the Climate System" (September 2021) was organized and a high-level implementation plan was developed. Currently, an article based on this implementation plan is being prepared for *BAMS*, a webinar series is being developed and links with the international detection and attribution group are being explored. For the WCRP Open Science Conference in Kigali, Rwanda in 2023, ESPESC and GEWEX jointly submitted a session proposal "Attribution and Prediction of Changes in Earth's water cycle". This session focuses on reservoirs, flux changes, precipitation extremes, and how to effectively combine observations and models to quantify, explain and predict changes in Earth's water cycle.

My Climate Risk (MCR) aims to develop and mainstream a "bottom-up" approach to regional climate risk, meaning a combination of hazard, vulnerability and exposure that is particular to a given regional context. This starts with the requirements of decision-makers. By developing a new framework for assessing and explaining regional climate risk and using all the available sources of climate information (observations, reanalysis, model simulations, better understanding, etc.), climate information will be made meaningful at the local scale. Whilst any application of the framework will inevitably be specific and tailored to local concerns, the framework itself will be generic, ensuring flexibility and applicable across a number of region types [large scale, urban, typical *Special Report for Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX) region, etc.]. The framework aims to become a much-needed support for the development of climate services. At the same time, MCR can identify needs to be addressed by the WCRP Core Projects and other Lighthouse Activities (e.g., implications of model biases).

MCR's science plan is accepted and in place. In this context, GHP-RHPs have been recognized as similar activities to what MCR plans to pursue. MCR's approach can be described as: "Small is beautiful (and

can be effective)". It promotes the importance of simplicity and building of relevant narratives/tools that people can relate to and will empower local communities. MCR's methodology embraces a bottom-up approach, starting from end users' needs, which are inherently local and case-specific, through regional hubs. Currently, there are eight regional hubs which are located in Australia, the Philippines, Nepal, Norway, Argentina, South Africa, Canada and the United Kingdom. In 2022, several activities have been co-organized, like the Mathematics of Planet Earth Virtual Summer School on attribution, causality, and decision-making (June 2022) and the Risk-Knowledge Action Network Workshop on understanding and modeling complex risks in coupled human-environment systems (February 2022).

Safe Landing Climates (SLC) is an exploration of the routes to climate-safe landing "spaces" for human and natural systems. It will explore present-to-future pathways for achievement of key Sustainable Development Goals (SDGs). The time scale is multi-decadal to millennial.
The working group identified five research themes that are currently being developed:

- *Safe Landing Pathways* aims to define what climate trajectories and destinations are safe/unsafe, and for whom, keeping in mind to preserve habitability and food security and identify adaptation limits. It uses a whole systems approach to account for climate risk along the climate trajectory, staying within planetary boundaries and drawing on quantification of climate risks. The strategy for this scientific theme is being developed.
- *Understanding High-Risk Events* identifies and characterizes risks from low-probability, high-impact possibility with global impact, e.g., "tipping points," risk of large carbon release, ice shelf/sheet collapse, large-scale extreme events, etc. The goal is to facilitate incorporation of uncertain risks into future projections, cost/benefit analysis and adaptation planning and foster Earth system models that can represent them probabilistically, and that account for relevant interactions. Additionally, it aims to identify adaptation limits and examine how, or if, tail risks and tipping points/tipping elements can be mitigated or avoided (or caused) by climate mitigation or geoengineering efforts. This theme is part of an ongoing webinar series on tipping points.
- *Perturbed Carbon Cycle* theme focuses on:
  - acceptability and climate implications of carbon dioxide removal (CDR) systems (including bioenergy with carbon capture and storage) while maintaining food and water supply, preserving biodiversity, and limiting ocean acidification
  - assessing possible contribution to mitigation by CH_4, N_2O, etc.
  - assessing risk of surprises or rapid changes in greenhouse gases due to land sources; implications for allowable greenhouse gas emissions under the Paris Agreement
  - building understanding of the coupled carbon-energy-water cycle
  - building on understanding of the coupled carbon-energy-water cycle drawing on process understanding developed in GEWEX
  - exploring impact on food and water supply, and biodiversity
  - fostering improved observation and modeling of terrestrial biogeochemistry.
- *Water Resources* looks at the impacts of climate change and direct human activity on the long-term redistribution of water in land-based natural systems/reservoirs and assesses implications of mitigation and adaptation scenarios.
- *Sea Level Rise* aims to quantify "acceptable" sea level rise and its rate and looks at its irreversibility on time scales ranging from multiple decades to millennia, while estimating the impact on low elevation lands communities and ecosystems.

There are many thematic touch points between SLC and GEWEX and opportunities to collaborate. Affiliate members are welcome to all working groups.

The objective and focus of the *WCRP Academy* (Academy) is to determine the requirements for climate research education, identify training gaps and build enabling mechanisms in order to train future generations of climate scientists. This will be both inward facing, which aims to consolidate and support WCRP training activities, and outward facing, which will bring together an even broader range of training opportunities. To build this marketplace (Fig. 19), the Academy will work with WCRP core activities, including the other LHAs, and established climate education providers, including universities. There will be an annual stock take to ensure that the Academy continues to meet the needs of the climate science community.

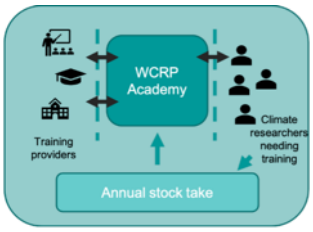

Fig. 19: The LHA WCRP Academy's marketplace

The Academy formed three working groups (WG):

- *WG 1 Stock-Take* aims to design a mechanism for understanding what training is available and what is needed. Looking at the long-term, it is necessary to decide how to operationalize this function. Currently, WG1 has developed a stock-take survey using set definitions for the terms climate science, climate scientist and climate science training. The first stock-take in the form of a survey has taken place in 2021. Results of this survey among a balanced group of respondents in terms of gender and country of residence can be summarized as follows:

  Most respondents:

  - completed a higher education level (BSc, MSc or PhD), usually in their own country
  - are affiliated with either a university, research institute or a government agency
  - have had further training within a certain range of type and focus since their highest qualification
  - speak English, Portuguese or Spanish

  The top four obstacles for respondents to personally access training or education that were mentioned are: financial barriers, limited knowledge of available options, lack of local expertise and limited online training availability. Training and educational opportunities the respondents would like to see the Academy offer include short courses, webinars by experts, seasonal schools and online lectures. The respondents indicated that useful resources on the Academy's web portal should include informal training options, networking and internship opportunities and targeted training to increase local capacity or expertise, like train the trainer initiatives.
- *WG 2 Identity and Portal* aims to establish a value-proposition and brand and to develop a web-portal. WG2 will guide the development of this platform in the long-term. At this time, a landing page, name, logo and portal requirements have been developed.
- *WG 3 Finance* aims to establish a business model to build proposals and options. The goal is to create a financial sustainable mechanism.

The second roundtable discussion themed "How to increase engagement in WCRP" focused on the Global South as countries in this region are not as active within WCRP as their counterparts in the North. To stimulate this discussion, a panel of representatives from the GEWEX SSG and GEWEX Panels with background and knowledge of this region were asked their view on the following four questions and statements followed by discussion:

- Should scientific expertise in the Global South be favored, or is it more important to run models or process huge data sets?
- Does specific research on the tropical and southern hemisphere climate needs to be promoted? *Is our research biased towards the northern hemisphere or not, and how do we need to combat that?*

- A strong observational network is key. Increasing awareness in the region for environmental monitoring is important. *How can we strengthen the observational network and conscience of the societies in the Global South that observation of the environment is essential in order to manage it and curate it for the future?*
- Investments are needed in PhD programs on environmental sciences to train the scientists and experts of tomorrow. *What needs to be done in order to invest in new scientific and technical expertise that will be able to manage the consequences of climate impacts on our resources?*

Means and suggestions for enhancing the collaboration between the Global North and South and do a better job at capacity development are:

- use existing structures and the regional, national and continental centers and global programs to establish long-term sustainability. Interaction between research communities-operational centers-stakeholders is key for the mutual development and the future management of the environment
- link training centers and expertise with universities and/or regional activities. In this context, it was also mentioned that globally, English is the main scientific language in academia. Making proficiency in English part of the educational program was suggested in order to have full access to all available knowledge.
- develop a policy regarding cyber security and open access to make data accessible for everyone
- form a regional network to manage access and processes to access observations for regional and outside people. Create operational and managerial infrastructures and the tools to maintain those.
- combine bottom-up (get issues raised) and top-down strategies

This theme will be further explored at the WCRP Open Science Conference.

2. GEWEX Panel Status Reports

2.1 Global Atmospheric System Studies Panel (GASS)

Full Panel Name (Acronym) : Global Atmospheric System Studies Panel (GASS)
Reporting Period : 01 January - 31 December 2022
Starting Date : 2018
End Date (where appropriate) : NA
URL : www.gewex.org/panels/global-atmospheric-system-studies-panel

Membership

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

Members and Term Dates : Ian Boutle, 2018 – 2022
Carla Gulizia, 2020 - Present
Irina Sandu, 2018 - 2022
Martin S. Singh, 2019 - Present
Shaocheng Xie, 2018 - Present
Yongkang Xue, 2018 - Present
Ann Fridlind, 2021 - Present
Pier Siebesma, incoming member
Philip Stier, incoming member
Claudia Stubenrauch, incoming member
Louise Nuijens, incoming member

Panel Objectives, Goals and Accomplishments during Reporting Period

Overall Panel Objective(s)

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

List of Panel Goals

Adjust yearly

- Sharpen the scientific goals of GASS
- Organize Pan-GASS conference (Monterey Jul 2022)
- Explore ideas for new GASS projects
- Maintain and develop collaboration with other GEWEX panels and WCRP communities (e.g. WGNE, CFMIP, lighthouses activities)
- Close and finalise two projects (COORDE and Demistify)
- Update panel composition according to pan-GASS outcome and new projects

List of Key Results

Adjust yearly with respect to goals

- Successful Pan-GASS conference in Monterey (25-29 Jul 2022, hosted by LLNL); GEWEX News article about its outcome (Klocke, Bony and Xie, 2022)
- Combined with pan-GASS: High-resolution model and ARM observation analysis competition for early career scientists, with the involvement of YESS (via GASS panel member and YESS member Carla Gulizia), with the support of DOE ARM and Germany Climate Service.
- Discussion and launch (near the end of 2022) of new GASS projects (COMBLE, Friction Experiment, EUREC4A-MIP, Deep convective organization, DYAMOND)
- Integration within GASS of GEWEX initiatives UTCC-PROES and GAP
- Revision of the GASS panel composition (new members: Pier Siebesma, Claudia Stubenrauch, Philip Stier, Louise Nuijens; stepping down: Irina Sandy and Ian Bouttle)
- Two projects reaching final stage (COORDE and Demistify), others in productive phase. Papers are being published in all projects.
- Strengthening of collaborations with CFMIP (date of pan-GASS meeting adjusted to be held right after CFMIP meeting, plans for a joint CFMIP/GASS meeting in 2023), WCRP lighthouse activity on km-scale modeling (DYAMOND is now an official GASS project and GASS aims at encouraging/developing the analysis of global CRM simulations), WGNE (development of km-scale modeling, GCM parameterizations)
- Discussions during pan-GASS with other GEWEX panels (GLASS, GHP) about potential collaborations (e.g. around km-scale modeling or convective organization)

Other Science Highlights

Not part of the 2-3 major accomplishments

Demistify (fog)

Objective: Understand and improve modelling and forecasting of radiation fog
Science questions:

- How well can models simulate the development of radiation fog?
- What are the key processes governing the development of radiation fog?
- What level of complexity required from NWP models to adequately simulate these processes?
- What role does land surface interaction play in the development of radiation fog?

Major results:

- Representation of cloud droplet sedimentation is essential for NWP fog simulation
- Small changes in fundamental parametrizations are more important to fog development than aerosol
- Publication: Bouttle et al., ACP (2022): https://acp.copernicus.org/articles/22/319/2022/

DCP (diurnal cycle of precipitation)

Goal: To understand what processes control the diurnal and sub-diurnal variation of precipitation over different climate regimes in observations and in models and identify deficiencies and missing physics in current GCMs to gain insights for further improving the parameterization of convection in GCMs.

Science questions:

What are the model deficiencies in simulating the diurnal cycle of precipitation using a hierarchical modelling approach including SCM, short-term hindcasts, and climate free-running simulations when compared with both satellite and field data over different convective regimes?

Major results:

- Modeled diurnal cycle phase is closely related to how convection is triggered, air parcel is launched, and mid-level convection is represented in cumulus parameterizations
- The weak amplitude of diurnal cycle of precipitation shown in climate simulations can be largely addressed in hindcasts, indicating that this model error is largely related to the error in the large-scale circulation and the interaction between convection and its environments in climate simulations

Publication:

- Tang, S., Xie, S., Guo, Z., Hong, S.-Y., Khouider, B., Klocke, D., et al. (2021) Long-term single-column model intercomparison of diurnal cycle of precipitation over midlatitude and tropical land. Q J R Meteorol Soc, 1– 29. Available from: https://doi.org/10.1002/qj.4222.

LS4P (surface and sub-surface temperature)

Science questions:

- What is the impact of the initialization of large scale LST/SUBT and snow pack, including the aerosol in snow, in climate models on the S2S prediction over different regions?
- What is the relative role and uncertainties in these land processes versus in SST in S2S prediction? How do they synergistically enhance the S2S predictability? This project focuses more on the process understanding and predictability rather than the operational S2S prediction.

Yearly goals:

- Complete the Phase I experiment for all the LS4P groups.
- Submit a LS4P paper to BAMS to disseminate the LS4P main results to the community.
- Prepare three main LS4P group papers for the *Climate Dynamics* LS4P special issue and submit them by the end of the 2022 summer.
- Submit seven LS4P papers to *Climate Dynamics* special issue by the LS4P Group members (four have been published).
- Kick off the LS4P Phase II experiment before the end of 2022.

Major results:

- The analyses of observational data show the persistence of the monthly mean T-2m anomaly. Those anomalies can persist for several months, especially during the spring, which suggest the land temperature in high mountain could be a potential source for the S2S predictability. Moreover, data analyses identify significant negative correlations between springtime T-2m anomalies in the Rocky Mountains and Tibetan Plateau, suggesting a possible intercontinental intersection, which may help enhance the S2S predictability.
- With an innovative initialization approach, the ensemble results from the 18 LS4P Earth System Models reveal for the first time that the Tibetan Plateau land temperature could be a substantial

source of S2S precipitation predictability. Nine hot spot regions over the globe have been identified, by comparing with the SST effect, the LST effect is probably as large as ocean surface temperature with different "hot spot" regions.

Publications:

- Xue, Y., Yao, T., Boone, A. A., Diallo, I., Liu, Y., Zeng, X., Lau, W. K.-M., Sugimoto, S., Tang, Q., Pan, X., van Oevelen, P. J., Klocke, D., Koo, M.-S., Lin, Z., Takaya, Y., Sato, T., Ardilouze, C., Saha, S. K., Zhao, M., Liang, X.-Z., Vitart, F., Li, X., Zhao, P., Neelin, D., Guo, W., Yu, M., Qian, Y., Shen, S. S. P., Zhang, Y., Yang, K., Leung, R., Yang, J., Qiu, Y., Brunke, M. A., Chou, S. C., Ek, M., Fan, T., Guan, H., Lin, H., Liang, S., Materia, S., Nakamura, T., Qi, X., Senan, R., Shi, C., Wang, H., Wei, H., Xie, S., Xu, H., Zhang, H., Zhan, Y., Li, W., Shi, X., Nobre, P., Qin, Y., Dozier, J., Ferguson, C. R., Balsamo, G., Bao, Q., Feng, J., Hong, J., Hong, S., Huang, H., Ji, D., Ji, Z., Kang, S., Lin, Y., Liu, W., Muncaster, R., Pan, Y., Peano, D., de Rosnay, P., Takahashi, H. G., Tang, J., Wang, G., Wang, S., Wang, W., Zhou, X., and Zhu, Y., 2021: Impact of Initialized Land Surface Temperature and Snowpack on Subseasonal to Seasonal Prediction Project, Phase I (LS4P-I): Organization and Experimental design, Geosci. Model Dev., 14, 4465–4494, https://doi.org/10.5194/gmd-14-4465-2021.
- Diallo, I., Y. Xue, Q. Chen, X. Ren, W. Guo, 2022: Effects of Spring Tibetan Plateau Land Temperature Anomalies on Early Summer Floods/Droughts over the monsoon regions of South East Asia. Climate Dynamics. DOI: 10.1007/s00382-021-06053-8
- Qiu, Yuan, Jinming Feng, Jun Wang, Yongkang Xue, Zhongfeng Xu, 2022: Memory of land surface and subsurface temperature (LST/SUBT) initial anomalies over Tibetan Plateau in different land models. Climate Dynamics. https://doi.org/10.1007/s00382-021-05937-z
- Xu, H, X-Z Liang, Y. Xue: 2022: Regional climate modeling to understand Tibetan heating remote impacts on East China precipitation. Climate Dynamics DOI: 10.1007/s00382-022-06266-5
- Xue Y., I. Diallo, A. A. Boone, T. Yao , Y. Zhang, X. Zeng, J. D. Neelin, W. K.M. Lau , Y. Pan, Y. Liu1, X. Pan, Q. Tang, P. J. van Oevelen, T. Sato, M.-S. Koo, S. Materia, C. Shi, J. Yang, C. Ardilouze, Z. Lin, Xin Qi, T. Nakamura, S. K. Saha, R. Senan, Y. Takaya, H. Wang, H. Zhang, M. Zhao, H. P. Nayak, Q. Chen, J. Feng, M. A. Brunke, T. Fan, S. Hong, P. Nobre, D. Peano, Y. Qin, F. Vitart, S. Xie, Y. Zhan, D. Klocke, R. Leung, X. Li, M. Ek, W. Guo, G. Balsamo, Q. Bao, S. C. Chou, P. de Rosnay, Y. Lin, Y. Zhu, Y. Qian, P. Zhao, J. Tang, X.-Z. Liang, J. Hong, D. Ji, Z. Ji, Y. Qiu, S. Sugimoto, K. Yang, M. Yu, 2022: Spring Land Temperature in Tibetan Plateau and Global-Scale Summer Precipitation – Initialization and Improved Prediction. Bulletin of American Meteorological Society. In review.

UTCC PROES (Upper Tropospheric Clouds and Convection Process Evaluation Study)

Goal: To advance our knowledge of climate feedbacks of UT clouds and therefore gain a better understanding of the interconnection between the convection and the properties of the outflowing anvils. The focus may be widened to the role of cirrus originating from in situ freezing driven by large-scale forcing, via a link to SPARC.

Science questions:

- understand relation between convection, cirrus anvils & radiative heating
- develop observational diagnostic methods to probe processes that detrain UT clouds from convection

Major results:

- release of two datasets (30N-30S, 2012-2016) from TOOCAN convective system tracking approach (https://toocan.ipsl.fr/)
- Expanded radiative heating rates (30N-30S, 2003-2018) from Machine Learning CIRS data & ERA Interim, trained with CloudSat-lidar data (radiative heating rates from FLXHR)
- Expanded vertical structure and precipitation (30N-30S, 2003-2018) from Machine Learning CIRS data & ERA Interim, trained with CloudSat-lidar data (GEOPROF, PRECIP-COLUMN)

Publications:

- Stubenrauch, C. J., G. Caria, S. E. Protopapadaki, and F. Hemmer, 3D radiative heating of tropical upper tropospheric cloud systems derived from synergistic A-Train observations and machine learning, Atmos. Chem. Phys., 21, 1015–1034, DOI:10.5194/acp-21-1015-2021 (2021)
- Takahashi, H., Z. Luo, and G. Stephens, Revisiting the Entrainment Relationship of Convective Plumes: A Perspective From Global Observations, Geophys. Res. Lett., 48, DOI:10.1029/2020GL092349 (2021)
- Detection and Tracking of Tropical Convective Storms Based on Globally Gridded Precipitation Measurements: Algorithm and Survey over the Tropics, J. Appl. Meteor. Clim., 60, 403-421, DOI:10.1175/JAMC-D-20-0171.1 (2021)
- Elsaesser, G., R. Roca, T. Fiolleau, A.D. Del Genio, and J. Wu, 2022: A simple model for tropical convective cloud shield area growth and decay rates informed by geostationary IR, GPM, and Aqua/AIRS satellite data. J. Geophys. Res. Atmos., 127, e2021JD035599, DOI:10.1029/2021JD035599 (2022)

Panel Activities during Reporting Period

List of Panel Activities and Main Result

- 1. Ongoing projects: see above
- 2. New GASS projects launched after the pan-GASS conference (2022):

Evaluating simulated convective clouds during Arctic cold-air outbreaks: A model intercomparison study (COMBLE):

- Goal: Assess the ability of numerical models to represent the intense Arctic cold-air outbreak observed during the Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE; Geerts et al., 2022).
- Coordinators: Tim Juliano, Florian Tornow and Ann Fridlind

EUREC4A-MIP:

- Goal: Understand and assess the model representation of the mesoscale organization of shallow convection
- Coordinators: Pier Siebesma, Christoph Schär and Sandrine Bony

Cumulus Friction Experiment:

- Goal: What is the impact of shallow convective momentum transport on the structure of the ITCZ?
- Coordinator: Louise Nuijens

Deep convective organization:

- Goal: Develop coordinated activities around the questions: How do we characterize convective organization? What are the main mechanisms underlying the organization? How does the organization affect the larger scales? On-going definition of the project...
- Coordinator: Martin Singh

DYAMOND:

- Goal: Develop global km-scale atmospheric and ocean climate models and encourage analysis of their simulations in connection with other GASS projects (https://easy.gems.dkrz.de/DYAMOND/index.html)
- Coordinator: Daniel Klocke

GAP:

- Goal: To enhance our understanding of aerosol-precipitation interactions on a regional to global scale with a focus on energy and water budget constraints.
- Coordinators: Philip Stier and Sue van den Heever

Science Issues and Collaboration during Reporting Period

Contributions to Developing GEWEX Science and the GEWEX Imperatives

a. Data Sets
   - all data relevant to GASS projects (forcing data, model output, and validation data) will be available to the community.
   - GASS to strengthen collaboration with GDAP regarding the potential of past and new satellite observations to address GASS science questions and new projects.
   - The LS4P data bank has been established in the TPE Big Data Center

b. Analysis
   - GASS projects are expected to develop new analysis tools and software that will be available to the community
   - UTCC-PROES and new project on Deep Convective Organization to participate in workshop discussing and comparing the different cloud tracking (and maybe cold pool tracking) algorithms
   - Ongoing discussions between GASS and GDAP about the development of a light satellite simulator for global km-scale models.
   - Wish of GASS to promote the community analysis of global km-scale simulations (DYAMOND)

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

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

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

f. Technology Transfer
   - GASS projects intends to transfer improved model treatments to weather and climate centers

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

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?

…….

2. Flux exchanges:

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

3. Precipitation Extremes:

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

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?
→ Convective organization and climate (in cooperation with CFMIP)

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)?

→ All projects

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?

→ All projects (on different scales)

4. Land-atmosphere interactions:

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

→ LS4P

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

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

Contributions to WCRP including the WCRP Light House Activities

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

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

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

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

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

Workshops and Meetings

List of Workshops and Meetings Held in 2022

Meeting title, dates and location

- Regular (every two months) video-conferences with all panel members
- Pan-GASS conference, 25-29 July 2022 : plenary and breakout group sessions

List of Workshops and Meetings Planned in 2023

Meeting title, dates and location and anticipated travel support needs

- CFMIP/GASS conference, July 10-13 2023, Paris

Other Meetings Attended On Behalf of GEWEX or Panel in 2022

- CFMIP, July 2022 (Seattle): S. Bony presented GASS activities
- GEWEX SSG 34A (in Paris) and 34B (in Monterey): presentation GASS activities

- WGNE, November 2022 (remote), D. Klocke presented GASS activities
- LS4P workshop, December 2022 (Chicago)
- COMBLE webinar, November 2022

Publications during Reporting Period

List of Key Publications

- Boutle, I., Angevine, W., Bao, J.-W., Bergot, T., Bhattacharya, R., Bott, A., Ducongé, L., Forbes, R., Goecke, T., Grell, E., Hill, A., Igel, A. L., Kudzotsa, I., Lac, C., Maronga, B., Romakkaniemi, S., Schmidli, J., Schwenkel, J., Steeneveld, G.-J., and Vié, B.: Demistify: a large-eddy simulation (LES) and single-column model (SCM) intercomparison of radiation fog, Atmos. Chem. Phys., 22, 319–333, https://doi.org/10.5194/acp-22-319-2022, 2022.
- Xue, Y., Yao, T., Boone, A. A., Diallo, I., Liu, Y., Zeng, X., Lau, W. K.-M., Sugimoto, S., Tang, Q., Pan, X., van Oevelen, P. J., Klocke, D., Koo, M.-S., Lin, Z., Takaya, Y., Sato, T., Ardilouze, C., Saha, S. K., Zhao, M., Liang, X.-Z., Vitart, F., Li, X., Zhao, P., Neelin, D., Guo, W., Yu, M., Qian, Y., Shen, S. S. P., Zhang, Y., Yang, K., Leung, R., Yang, J., Qiu, Y., Brunke, M. A., Chou, S. C., Ek, M., Fan, T., Guan, H., Lin, H., Liang, S., Materia, S., Nakamura, T., Qi, X., Senan, R., Shi, C., Wang, H., Wei, H., Xie, S., Xu, H., Zhang, H., Zhan, Y., Li, W., Shi, X., Nobre, P., Qin, Y., Dozier, J., Ferguson, C. R., Balsamo, G., Bao, Q., Feng, J., Hong, J., Hong, S., Huang, H., Ji, D., Ji, Z., Kang, S., Lin, Y., Liu, W., Muncaster, R., Pan, Y., Peano, D., de Rosnay, P., Takahashi, H. G., Tang, J., Wang, G., Wang, S., Wang, W., Zhou, X., and Zhu, Y., 2021: Impact of Initialized Land Surface Temperature and Snowpack on Subseasonal to Seasonal Prediction Project, Phase I (LS4P-I): Organization and Experimental design, Geosci. Model Dev., 14, 4465–4494, https://doi.org/10.5194/gmd-14-4465-2021.
- Stubenrauch, C. J., G. Caria, S. E. Protopapadaki, and F. Hemmer, 3D radiative heating of tropical upper tropospheric cloud systems derived from synergistic A-Train observations and machine learning, Atmos. Chem. Phys., 21, 1015–1034, DOI:10.5194/acp-21-1015-2021 (2021)
- Takahashi, H., Z. Luo, and G. Stephens, Revisiting the Entrainment Relationship of Convective Plumes: A Perspective From Global Observations, Geophys. Res. Lett., 48, DOI:10.1029/2020GL092349 (2021)
- Tang, S., Xie, S., Guo, Z., Hong, S.-Y., Khouider, B., Klocke, D., et al. (2021) Long-term single-column model intercomparison of diurnal cycle of precipitation over midlatitude and tropical land. Q J R Meteorol Soc, in revision
- Boutle, I., Angevine, W., Bao, J.-W., Bergot, T., Bhattacharya, R., Bott, A., Ducongé, L., Forbes, R., Goecke, T., Grell, E., Hill, A., Igel, A. L., Kudzotsa, I., Lac, C., Maronga, B., Romakkaniemi, S., Schmidli, J., Schwenkel, J., Steeneveld, G.-J., and Vié, B.: Demistify: a large-eddy simulation (LES) and single-column model (SCM) intercomparison of radiation fog, Atmos. Chem. Phys., in revision.
- van Niekerk, A., Sandu, I., Zadra, A., Bazile, E., Kanehama, T., Köhler, M., et al. (2020). COnstraining ORographic Drag Effects (COORDE): A model comparison of resolved and parametrized orographic drag. Journal of Advances in Modeling Earth Systems, 12, e2020MS002160. https://doi.org/10.1029/2020MS002160
- Tang, S., Gleckler, P., Xie, S., Lee, J., Ahn, M., Covey, C., & Zhang, C. (2021). Evaluating the Diurnal and Semidiurnal Cycle of Precipitation in CMIP6 Models Using Satellite- and Ground-Based Observations, Journal of Climate, 34(8), 3189-3210, https://doi.org/10.1175/JCLI-D-20-0639.1.
- Galarneau, T. and X. Zeng, 2021: Influence of Midlatitude Soil Moisture Conditions on Upstream Subtropical Circulation, GEWEX Quarterly, Vol. 31, No. 1, p. 6-7.

2.2 GEWEX Data and Analysis Panel (GDAP)

Full Panel Name (Acronym) : GEWEX Data and Analysis Panel (GDAP)
Reporting Period : 01 January 2021 - 31 December 2021
Starting Date : N/A
End Date (where appropriate) : N/A
URL : https://www.gewex.org/panels/gewex-data-and-analysis-panel/

Membership

Chair(s) and Term Dates : Rémy Roca (2016–Present)
Tristan L'Ecuyer (2016–Present)

Members and Term Dates : Ali Behrangi (2020–Present)
Hélène Brogniez (2020–Present)
Eui-Seok Chung (2019–Present)
Andrew Heidinger (2011 - Present)
Seiji Kato (2017–Present)
Hirohiko Masunaga (2010–Present)
Isable Trigo (2017–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

Adjust yearly

- *Provide expertise to support the analysis of satellite datasets, many of which were developed with the support of GDAP or GRP (e.g. ISCCP-NG, GPCP, SRB, SeaFlux, LandFlux)*
- *Oversee dataset assessments to provide critical uncertainty information for data records and identify gaps and future needs - promote best practices*
- *Support ground based networks (e.g. BSRN, ISMN)*
- *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)*
- *Provide guidance to space agencies and raise awareness of upcoming missionsRepresent GEWEX to funding agencies and the within the science community*

- *List of 2 to 3 Key Results*

Adjust yearly with respect to goals

- Added three new panel members (Benoit Meyssignac, Maria Hakuba, and Helen Brindley) with strong ties to future radiation budget missions (Libera and FORUM)
- Precipitation Assessment published in June 2021
- EEI study has revealed that Ocean Heat Uptake (OHU) estimates from the geodetic approach exhibit a significant increase of 0.4 Wm-2 per decade over 2002-2020 consistent with CERES EBAF TOA flux
- Coordinated the development and release of the prototype ISCCP-NG Level-1 Gridded (L1G) dataset spanning the year 2020 with a spatial resolution of 0.05 degrees and a temporal resolution of 30 minutes

Other Science Highlights

Not part of the 2-3 key results

- An inconsistancy has been revealed between CERES EBAF TOA flux and OHU estimated from the geodetic approach in 2017-2019 due to the non closure of the sea level budget
- Version 2 of the G-VAP archive has been completed
- The EUMETSAT Climate Monitoring Satellite Application Facility (CM-SAF) cloud algorithms were implemented on ISCCP-NG L1g data

Panel Activities during Reporting Period

List of Panel Activities and Main Result

Summary of Working Groups (Projects) Report

- ISCCP-NG: One trial year of calibrated L1 radiances for all common channels across the ring of geostationary satellites has been produced. A breakout sub-group meeting was held at the International Cloud Working Group (ICWG) to gather feedback on the prototype L1g dataset and discuss possible L2 products.
- EEI Assessment: Progress toward establishing consistency between Ocean Heat Update and variations in top of atmosphere radiation.
- Cloud Assessment Phase II: Initial comparisons of submitted datasets revealed problems with some fields stemming from algorithm changes and/or modified outputs. Updated versions of several datasets have been gathered and analysis is proceding including some new comparisons targeting applications not addressed in Phase I.
- Water Vapor Assessment Phase II: All activities outlined in the assessment plan are progressing. Analyses have identified a distinct spatial distribution of mainly wet biases that are dominated by large-scale circulations for the mid to high latitudes and by the diurnal cycle of clouds and the position of the ITCZ in tropical and subtropical regions. Dry biases are mainly observed over stratocumulus regions.

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

- Extending ISCCP L1g through early 2023 to test replacing GOES-17 with GOES-18
- Implementing NOAA/NESDIS Pathfinder Atmospheres (PATMOS-x) cloud algorithms on ISCCP-NG L1G and comparing against CM-SAF output.

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

- GASS: Scoping activity centering on convective organization in models and satellite observations; applying simulators to assess representation of clouds and convection in km-scale global models (both anticipated to start in spring 2023 and run for ~3 years; lead TBD).
- GLASS: Assessing the consistency between surface energy and water fluxes and temperature/soil moisture variations at local, regional, and global scales (workshop in April 2023; analysis from 2024-26; lead TBD).
- GHP: Coupling hydrology-motivated high time/space resolution satellite precipitation products to Regional Hydroclimate Products (RHPs) (early 2023-2026; lead TBD)
- Assessment of convective object tracking methods (related to UTCC and km-scale modeling activities) (workshop in spring 2023; GDAP lead: Thomas Fiolleau)
- Initiate a comprehensive analysis of the ISCCP and ISCCP-NG from 2020-present to understand how the two compare and to qunatify the improvements of the increased information of the new geostationary imagers compared to the ISCCP baseline (timeline TBD; Lead: Andrew Heidinger)

Science Issues and Collaboration during Reporting Period

Contributions to Developing GEWEX Science and the GEWEX Imperatives.

a) Data Sets

- Reference Ocean Heat Content and Ocean Heat Uptake products
- G-VAP data archive http://dx.doi.org/10.5676/EUM_SAF_CM/GVAP/V001
- GEWEX Integrated Product
- ISCCP-NG

b) Analysis

- Methods for estimating EEI from in situ data and altimetry minus grace data
- Trends, regression and variations in water vapour data records.
- Consistency frameworks for assessing independent flux estimates
- Cloud tracking workshop and ISCCP-NG support global cloud lifecycle studies

c) Processes

- Climate change observed in water vapour data.

d) Modeling

- Improved models of surface radiative fluxes through the RAdiation transfer Model Intercomparison (RAMI)

e) Application

- Water vapour residence times in data from satellite, reanalysis and climate models important for forecasting.

f) Technology Transfer

- NA

g) Capacity Building

- NA

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?

Water vapor, an important reservoir of water in the climate system, is being analyzed to establish the dependence of TCWV on temperature over land within G-VAP. It is anticipated that only a start will be done as the dependencies are far more complex over land, with stronger violations of assumptions entering Clausius-Clapeyron relative to over ocean. ISCCP-NG can play a role in the plans of GEWEX by eventually providing global (geo) and highly time and space resolved data. It's still in a development phase and won't contribute directly (this answer is applied to all of the goals). ISCCP-NG will provide information on clouds, precipitation and clear-sky water vapor since it contains the full spectral content of the advanced imagers.

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?

Precipitation assessment quantifies uncertainties in water exchanges between the atmosphere and surface. ISCCP-NG may contribute to better understanding energy fluxes when L2 products mature.

3. Precipitation Extremes:

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

Precipitation assessment included a section discussing the representation of rainfall extremes in satellite datasets

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 estimates with robust uncertainty estimates support this goal by:

(1) Constraining estimates of the global climate feedback parameter and the climate sensitivity;

(2) Providing temporal variations in EEI central to time variations of the global climate feedback parameter and the effective climate sensitivity;

(3) Linking temporal variations in EEI to temporary global radiative dampening or enhancement and the surface warming pattern changes;

(4) Constraining the global water-energy budget fluxes involved in the global water budget. ISCCP-NG should contribute to climate feedback studies since its data provides information linking cloud, aerosol, surface charactistics, and water vapor

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)?

Water Vapor Assessment Phase II element on boundary layer water vapor has found that evaporation dominates the water vapour content in the ABL on the global ice-free ocean scale.

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?

   NA

4. Land-atmosphere interactions:

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

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

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

1. Anthropogenic forcing of continental scale water availability:

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

NA

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?

NA

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?

Climate change and associated feedback mechanisms lead to an increase in TCWV over ocean. Work is in progress to use G-VAP to assess the picture over land which is less clear.

Other Key Science Questions

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

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

Contributions to WCRP including the WCRP Light House Activities

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

- Panel member Benoit Meyssignac serves on LA: Explaining and Predicting Earth System Change
- *Cooperation with other WCRP Projects, Outside Bodies and links to applications*

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

- EEI assessment activity is coordinated with CLIVAR

- SPARC representatives are invited to G-VAP workshops and vice versa. Occassionally representatives participate in each others workshops.
- G-VAP established links to the ESA CCI programme, to EUMETSAT CM SAF and ROM SAF, to IROWG, to the IPWG/GEWEX precipitation assessment and to the UTCC PROES
- G-VAP is represented within the ESA EO4society program through a ESA living planet fellowship and a Sentinel 5p Innovation project (focused on stable water vapour isotopologues)

Workshops and Meetings

List of Workshops and Meetings Held in 2021

Meeting title, dates and location.

- 3rd ICWG ISCCP-NG Topical Meeting November 2022 (Tbd).
- ISCCP-NG Presentations given at ESA Living Planet Symposium and the EUMETSAT Meteorological Conference.
- EEI assessment has held quarterly virtual meetings
- G-VAP has held three virtual meetings

List of Workshops and Meetings Planned in 2022 and 2023

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

- SSG-34a/b
- 17th BSRN Scientific Workshop
- GDAP Panel Meeting and ISSI Energy Balance Workshop (Bern, September 2022)
- G-VAP internal workshop (Copenhagen, October 2023)
- 2nd EEI Workshop (spring 2023)
- ISCCP-NG L1G Working Group October 26, 2022
- 2nd ISCCP-NG Community Workshop (TBD, 2023)

Other Meetings Attended On Behalf of GEWEX or Panel in 2021

- NA

Publications during Reporting Period

List of Key Publications

- Crewell, S., Ebell, K., Konjari, P., Mech, M., Nomokonova, T., Radovan, A., Strack, D., Triana-Gómez, A. M., Noël, S., Scarlat, R., Spreen, G., Maturilli, M., Rinke, A., Gorodetskaya, I., Viceto, C., August, T., and Schröder, M., 2021: A systematic assessment of water vapor products in the Arctic: from instantaneous measurements to monthly means, Atmos. Meas. Tech., 14, 4829–4856, https://doi.org/10.5194/amt-14-4829-2021.
- Calbet, X., Carbajal Henken, C., DeSouza-Machado, S., Sun, B., and Reale, T.: Small scale variability of water vapor in the atmosphere: implications for inter-comparison of data from different measuring systems, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2022-111, in review, 2022.
- He, J., Brogniez, H., and Picon, L.: Evaluation of tropical water vapour from CMIP6 GCMs using the ESA CCI "Water Vapour" climate data records, Atmos. Chem. Phys. Discuss. [preprint], https://doi.org/10.5194/acp-2021-976, in review, 2022.Chenal, J., Meyssignac, B., Ribes, A., & Guillaume-Castel, R. (2022). Observational Constraint on the Climate Sensitivity to Atmospheric CO2 Concentrations Changes Derived from the 1971–2017 Global Energy Budget, Journal of Climate,

35(14), 4469-4483. Retrieved Jul 13, 2022, from https://journals.ametsoc.org/view/journals/clim/35/14/JCLI-D-21-0565.1.xml

- Marti, F., Blazquez, A., Meyssignac, B., Ablain, M., Barnoud, A., Fraudeau, R., Jugier, R., Chenal, J., Larnicol, G., Pfeffer, J., Restano, M., and Benveniste, J.: Monitoring the ocean heat content change and the Earth energy imbalance from space altimetry and space gravimetry, Earth Syst. Sci. Data, 14, 229–249, https://doi.org/10.5194/essd-14-229-2022, 2022.
- 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.
- Heidinger, A.K.; Foster, M.J.; Knapp, K.R.; Schmit, T.J. Using GOES-R ABI Full-Disk Reflectance as a Calibration Source for the GOES Imager Visible Channels. Remote Sens. 2022, 14, 3630. https://doi.org/10.3390/rs14153630
- 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

2.3 GEWEX Hydroclimatology Panel (GHP)

Full Panel Name (Acronym) : GEWEX Hydroclimatology Panel (GHP)
Reporting Period : 01 January - 31 December 2021
Starting Date :
End Date (when applicable) : NA
URL : https://www.gewex.org/panels/gewex-hydroclimatology-panel/

Membership

Chair(s) and Term Dates : Francina Dominguez, 2018 - Present
Ali Nazemi, 2020 - Present

Members and Term Dates : Paola Arias, 2019 - Present
Rowan Fowley 2021 - Present
Li Jia, 2019 - Present
Xin Li, 2016 - Present
Santosh Pingale, 2022 - Present*
Andreas Prein, 2019 - Present
Joshua Roundy, 2020 - Present
Vidya Samadi, 2019 - Present
Anna Sörensson 2021 - Present
Ivana Stiperski, 2019 - Present

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 ot from an integrated perspective.

List of Panel Goals

Adjust yearly

- The GEWEX Hydroclimatology Panel (GHP) aims to provide an improved understanding of environmental water and energy exchanges to form an integrated perspective from local to continental scales suitable for hydrologic applications. Addressing the water cycle at the regional scale allows us to better understand processes the affect natural to socio-economic aspects of freshwater availability and demand.
- GHP includes four types of activities to achieve the mentioned tasks: (1) Regional Hydroclimatological Projects (RHPs) that are integrated regional programs for understanding and predicting hydroclimates in a particular region by bringing together various disciplines on water-related issues; (2) Cross-Cutting Projects (CCs), allowing GHP to propagate
- knowledge from one region to another, to synthesize results at the global scale and facilitate developing and testing of applications derived from new understandings; (3) Global Data Centers, collecting and distributing important hydrology-related data; and (4) Networks, maintaining

collaboration and capacity building activities that not yet structured as a RHP, or as an alternative for the larger RHP structure.

List of Key Results

Adjust yearly with respect to goals

- GHP has ONE internal and ONE annual panel meeting during 2021. The 2021 annual GHP meeting was the second fully virtual meeting of our panel. It showed that GHP activities continued to adapt to the ongoing pandemic, making progress despite limitations as a result of Covid-19 related travel and in-person meeting restrictions.
- Current RHPs, i.e. Global Water Future (GWF) and Baltic Earth, continue to be the two mature flagship RHPs with clear contributions to the science, practice, and policy-making. While focused on Canada, GWF is now expanding through collaborations with other RHPs and CCs. The panel is pleased to see how GWF is including Indigenous knowledge and views on water. Baltic Earth reported major progress on dissemination of the project results through a comprehensive special issue on the past, current and future of the Earth System in the Baltic region, along with fact sheets for stakeholders and policy makers.
- During the 2021 meeting, the Regional Hydrology Program for the Andes (ANDEX) submitted their science plan. The science plan was based in part on their white paper which consits of a series manuscripts published in the Frontiers journal. The panel recently provided feedback on the science plan and we are happy to announce that ANDEX is now an initiating RHP.
- We are enthusiastic about the three prospective RHPs that are quite advanced and almost ready to launch: the Asian Precipitaiton Experimentss (AsiaPEX), the Third Pole Environment-Water Sustainability (TPE-WS), and the United States RHP (US-RHP). It is expected that Science Plans for AsiaPEX and TPE-WS will be reviewed by the panel in 2022.
- HyMeX-2 is envisioned as the second phase of HyMeX RHP. The activity is now building support as a new generation of researchers takes the helm. The HyMex-2 team has submitted two proposals and have were involved in the Land Surface Atmosphere Interactions over the Iberian Semi-Arid Environment (LIAISE) campaign.
- The ongoing CC, Transport and Exchange Proceses in the Atmosphere over Mountains Experiment (TEAMx), which is progressing very well. The group organized a workshop with nearly 200 participants. There is exceptional opportunity for knowledge sharing between TEAMx and the other RHPs and CC.
- The International Network for Alpine Catchment Hydrology submitted their Phase II (INARCH-II) activity proposal. One key focus of INARCH's second phase will be on human-water interactions in mountainous regions and downstream areas. We are happy to report that after review from the panel, INARCH-II is our newest CC.
- Four prospective CCs are at different stages of organization. Determining Evapotranspiration (dET) CC and the Irrigation CC are joint initiatives between GHP and GLASS panels. dET focuses on advancing the understanding and determination of evapotranspiration across scales. They have had two workshops which have resulted into working groups. dET has also greatly benefited from the LIAISE campaign and potential links to AmeriFlux. The irrigation CC focuses on intercomparison of irrigation algorithms in current Earth System models. They had their first workshop online in early November 2021. The new Flood CC, will focus on understanding flood processes from observation to model
- development to socio-economic impact assessments. They published their first newsletter article and started to build a community. Monterrain CC has started recruiting team members through a

special issue and plans for a kickoff workshop in the Fall of 2022, they are currently seeking lead researchers to spearhead the CC.

- The Global Precipitation Climatology Centre (GPCC) and the Global Runoff Data Centre (GRDC) Data Centers are both making steady and significant progress. The panel had discussions as to how the International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE) can collaborate with similar initiatives outside GHP and GEWEX.
- PannEx, previously an initiating RHP, aiming at providing a better understanding of Earth system processes over the Pannonian Basin, has become a successful GHP Network. During 2021, the network published a special issue with 14 contributions on understanding of Earth System processes over the Pannonian Basin. The team was also awarded funding for a new project on micrometeorological measurements and analyses.
- The panel regretted to see the sunset of the Australian Energy and Water Exchanges research initiative (OzEWEX).

Other Science Highlights

Not part of the 2-3 major accomplishments

- The panel welcomed two new panel members during the 2021 meeting: Rowan Fowley from Maynooth University of Ireland who is actively involved with the use of Artificial Intelligence in observing and modeling land surface processes. Anna Sörensson from the University of Buenos Aires in Argentina was heavily involved with the Intergovernmental Panel on Climate Change (IPCC) sixth assessment report (AR6), particularly in terms of linking global to regional climate change.
- GHP has a new self-nomination system through which we have been able to link with broader community. The system resulted in recurruting new researchers that although not appointed in the panel, they are mapped into envisioned activities.
- Ali Nazemi and Paola Arias continue to represent GHP in the World Climate Research Program's My Climate Risk. Ali Nazemi also represents GHP in Interim Coordinating Committee (ICG) of the new WCRP Home for Regional Information for Society (RifS).

Panel Activities during Reporting Period

List of Panel Activities and Main Result

Regional Hydroclimate Projects (RHP's)

- Baltic Earth continues to progress steadily. The main achievement during this period has been the BEAR Assessment reports. These reports assess the current state of knowledge in topics such as Salinity dynamics in the Baltic Sea, Land-Sea biogeochemical linkages, Natural hazards and extreme events in the Baltic Sea region. The group also held summer and winter schools and the 3rd Baltic Earth Conference.
- Global Water Futures GWF has made important scientific advances including support for disaster warning from floods, droughts and water quality, changing water futures through modeling solutions for Canda and similar cold regions. They have led a Canadian national water modelling strategy, providing a national-scale capability that is made freely available to users. They have advanced a data management strategy and links with artists through a virtual water gallery. GWF is expanding beyond Canada to regions in the Americas, Asia and Europe.

- Current CrossCutting Projects (CC's):
- TEAMx has been very active during 2021. The first draft of the Plan for the TEAMx Observational Campaign was prepared by the Field Observations Committee and was shared with the TEAMx

community in March 2021. Preliminary work to establish a network of mountain weather and climate research projects. The Second TEAMx Workshop took place on 10-12 May 2021 and was a major TEAMx event with over 180 registered participants. The team published a BAMS article and GEWEX newsletter.

- Current Data Centers:
- The Global Precipitation Climatology Centre (GPCC) continues steady and significant progress. They increased the data base of quality-controlled stations to more than 123,700 stations (84,800 stations with climatological normals) and regularly update the quasi-operational monthly Monitoring Product and First Guess Products (daily and monthly).
- The Global Runoff Data Centre (GRDC) focuses on acquisition harmonization, and storage of global historical river discharge data. They released the web applications for access to GRDC spatial products and database status.
- The International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE) continues to progress despite limited resources, they collect data and are building collaborations with the Laboratory of Study of Geophysics and Oceanography from Space at CNES, France.

- Current Networks:
- The PANNEX network published a special issue of Atmosphere (ISSN 2073-4433). This special issue belongs to the section "Climatology". Special Issue "Climate Extremes in the Pannonian Basin: Current Approaches and Challenges" Prof. Dr. Adina-Eliza Croitoru Guest Editor, Published Papers: 14 papers listed in the "Key publications". The team was also awarded funding for a new project on micrometeorological measurements and analyses.

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

- ANDEX submitted their implementation plan during the GHP meeting. The White Book, which was largely a compilation of papers published in Frontiers, provided a strong peer-reviewed basis for their implementation plan. After the GHP meeting, the panel discussed and provided feedback to the ANDEX leadership. We were glad to welcome ANDEX as our newest initiating RHP.
- INARCH-II submitted their proposal as a continuation of the very successful INARCH CC. It has grown to a network of 50 research scientists with wide-ranging expertise from around the world, and 29 experimental research basins in 14 countries covering key mountain regions on most continents. The panel provided feedback and was happy to wecome INARCH-II as our newest CC.

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

- Asian Precipitaiton Experimentss (AsiaPEX) includes a strong and engaged community studying Asian land precipitation for prediction, disaster reduction and sustainable development. The group has been advancing with publications, documenting observations and estimation, as well as process studies and analyses of predictability.We expect a Science Plan this year.
- Third Pole Environment-Water Sustainability (TPE-WS) has very strong research teams in addition to large and well-funded infrastructure. Work includes runoff of 13 TP rivers, plant uptake of CO2, risk of glaciaal lake outburst. They have constructed 18 PBL towers, 9 microwave radiometers and lake measurements. We have not received a Science Plan.
- US RHP is now a cohesive multi-institutional effort to understand and address a changing hydroclimate in the United States, closing the gap between models and observations and determining the energy and water budgets at the surface. The core is an observational network and

a 40-yr CONUS simulation. The group has been meeting throughout the year to build consensus on research priorities. We expect a Science Plan this year.

- Determining ET is a prospective CC focused on analyzing issues related to evapotranspiration in a coordinated way. The 2nd CC-ET workshop was held successfully and the LIAISE campaign was completed. They published a report on GEWEX news and identified potential work lines.
- The irrigation CC focuses on intercomparison of irrigation algorithms in current Earth System models. They had their first workshop online in early November 2021.
- The new prospective Flood CC, will focus on understanding flood processes from observation to model development to socio-economic impact assessments. They published their first newsletter article and started to build a community.
- The prospective Monterrain CC has started recruiting team members through a special issue and plans for a kickoff workshop in the Fall of 2022, they are currently seeking lead researchers to spearhead the CC.

Science Issues and Collaboration during Reporting Period

Contributions to Developing GEWEX Science and the GEWEX Imperatives.

a. Data Sets

- The active RHPs (Baltic Earth and GWF) maintain their datasets and generate new ones as their activities progress, either with new campaigns or with the expansion of their networks.
- In TEAMx, new instrumentation is being tested and installed to extend the i-Box supersite in the Inn Valley Target Area. Publication of datasets for the Inn Valley as part of the TEAMx-endorsed CROSSINN project, e.g., Gohm et al., 2021 (https://doi.org/10.5281/zenodo.4585576)
- INARCH-II has adopted a philosophy and commitment to open data, with major efforts to compile these data, e.g., ESSD special issue "Hydrometeorological data from mountain and alpine research catchments" with 23 datasets (https://inarch.usask.ca/datasets-outputs/mountain-hydrometeorological-data.php and https://www.earth-syst-sci-data.net/special_issue871.html).
- GRDC continues to provide river discharge data as required.
- Next release of the GPCC precipitation data product portfolio (V.2021) comprising daily and monthly Full Data analyses, scheduled for Dec. 2021.
- The PanEx network has contributed to the Global Sub-Daily Rainfall (GSDR) dataset: The international effort made through collaboration in the PannEx initiative with INTENSE GEWEX Cross Cut contributes to enlarging the data availability for regional and global analysis of sub-daily precipitation extremes. See the article: .Lakatos et al. 2021 https://doi.org/10.3390/atmos12070838

b. Analysis

- GHP activities use the same basic information and input protocols for analyses of existent data bases, data from experimental campaigns and numerical modelling to have a comprehensive description of the physical processes.

c. Processes

- Each GHP activity focusses on some particular aspects. The main focus of Baltic Earth is to provide a better understanding complex physical and biogeochemical processes in the Baltic Sea region. GWF focus in on changing climate, land, hydrology and ecosystems as well as water management in cold regions. Joint LIASE effort between HyMeX-II and dET focuses on land

atmospheric processes in semi-arid regions with large human influences. TEAMx focuses on atmospheric transport and exchange proceses over mountains, while INARCH-II focuses on better understanding of hydrological processes in alpine cold regions with consideration on impacts on downstream environmental and socio-economic activities. These two effort together can provide a set of comprehensive finding regarding atmospheric, cryospheric and hydrologic processes that affect freshwater availability within and downstream of mountanious regions.

d. Modeling

- Due to the diversity in reseach questions, purposes and processes within different GHP activities, a varity of model types and simulation strategies are used. In the study of processes, often detailed modelling schemes are used at fine spatial and temporal scales, including single-column modelling, large-eddy simulation and high-resolution mesoscale modelling. At large scales relevant to climate studies, models range from regional models across a variaty of scales and/or process representations to global Earth System models with century-long simulations. Impact of severe weather events are usually studied with mesoscale models, often taking advantage of operational forecasting systems.

e. Application

- The overall objective of the GHP activities is to generate datasets, modeling methodologies and assessment frameworks that can serve the society through improved regional Meteorological and Hydrological Services.

f. Technology Transfer

- Datasets, model parameterization, benchamrkings and intercomparisons obtained as a result of GHP activities have a direct impact in the day-to-day operational activities of weather and climate modelling centers, for instance by providing improved reanalyses, observed timeseries and statistics including trends and variabilities. Also, one of the goals during the 2020 GHP meeting was to facilitate knowledge transfer between upcoming and mature RHPs.

g. Capacity Building

- In most of the GHP activities capacity building is high, firstly because of the continuous improvement of the scientific and technical capabilities of the personnel involved and secondly because there is a sustained flow of PhD subjects related to the actions that contribute to the maintenance, renewal and eventually enlargement of the related scientific community.

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?

GHP focuses on reservoirs on earth through the TPE initiating RHPs and HYDROLARE cross-cut.

An important fous of TPE is the measurement and understanding of glaciers and how they change in as climate continues to warm.

The International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE) continues to progress on lake observations despite limited resources, we are hoping to engage remote sensing

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?

GHP activities related to flux exchange include processes related to precipitation, runoff and evapotranspiration.

The Global Precipitation Climatology Centre (GPCC) is a critical resouce for precipitation data throughout the world.

The Global Runoff Data Centre (GRDC) focuses on runoff data at the global level.

Prospective dET is focused on evapotranspiration flux and how it can be better predicted.

3. Precipitation Extremes:

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

All the RHPs include a focus on changes in precipitation under a climate change. We currently do not have specific activites related to extreme precipitation.

Global Water Futures includes support for disaster warning from floods, droughts and water quality, changing water futures through modeling solutions for Canda and similar cold regions

The prospective RHP Asian Precipitaiton Experiments (AsiaPEX) includes a strong and engaged community studying Asian land precipitation for prediction, disaster reduction and sustainable development.

Goal # 2 (GS2): Quantify the inter-relationships between Earth's energy, water and carbon cycles to advance our understanding of the system and our ability to predict it across scales:

1. Forcing-feedback understanding:

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

The Baltic Earth and ANDEX RHPs have an explicit focus on feedbacks from the oceanic and terrestrial perspective.

The two The ANDEX Initiating RHP has a strong focus on deforestation and its feedbacks to the atmosphere.

Land-sea biogeochemical linkages are a main focus of Baltic Earth.

2. ABL process representation:

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

The TEAMx cross cut is entirely focused on a better understanding of the ABL over mountainous terrain, including the fluxes of energy, moisture and scalars.

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?

We currently do not have activities with a specific focus on circulation controls.

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?

Determining ET is a prospective cross-cut focused on better understanding and determinig evapotranspiration. ANDEX intitiating RHP has a strong focus on deforestation and land-atmosphere interactions.

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?

The three active RHPs; Baltic Earth, GWF and Andex are all committed to understanding how changing greenhouse effect has modified the water cycle over different regions.

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?

For decades, the GWF RHP has had strong connections with water managers. GWF has an advanced a data management strategy and links with artists through a virtual water gallery. GWF includes indigenous knowledge. As stated before, the ANDEX initiating RHP has a strong interest in deforestation in the Amazon-Andes transition region.

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?

All of our activities have the underlying focus of better understanding how anthropogenic climate change affects the regional and continental water cycles. In particular the RHPs, Baltic Earth, GWF and ANDEX, are all committed to understanding how water and land use and climate change affect the variability of extremes in their regions of analysis.

Other Key Science Questions

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

- Monitor water use and water allocation over land and to Introduce processes related to water management in models
- Improved characterization of evapotranspiration across scales and media and its representation in models.
- Better alignment with WCRP Lighthouse activities - in particular "My Climate Risk" and new RifS activity by strengthening effectively community work regionally (through RHPs) and across regions (through CCs and other actions). Some coordination from GHP is anticipated.

Contributions to WCRP including the WCRP Light House Activities

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

GWF's science goals are directly aligned with Light House Activities, particularly with 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 change 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.
There are multiple connections between ANDEX and the Working Group on Science and Research of the MCR's South America hub. First joint meeting was held in July 2022.

US-RHP has engaged with WCRP Digital Earth Lighthouse co-leads. Using the US-RHP to enable and inform a regional 'digital twin' is now considered in the development of the US-RHP science plan. Regional Digital Earths are one of the pillars of the WCRP Digital Earth Lighthouse. US-RHP also interacted with GWF and TEAMx.
INARCH, TEAMx and dET goals are directly aligned with 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 change on global and regional scales, with a focus on multi-annual to decadal timescales

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

- Within GEWEX: cooperation is sustained with the other panels (GDAP, GASS and GLASS). Our GLASS representative Josh Roundy serves as a link.
- Within WCRP: by its regional nature over land, there is interaction with CliC related to the GHP activities in high mountains and high latitudes. Cooperation with CORDEX is increasing as each RHP is interested in performing regional climate studies.
- The prospective AsiaPEX RHP will strengthen collaborations with the CLIVAR Monsoon Panel.
- With Future Earth: there are contacts with the research action iLEAPS (Integrated Land Ecosystem-Atmosphere Processes Study) in the building the ET CC.

Workshops and Meetings

List of Workshops and Meetings Held in 2020
Meeting title, dates and location.

- 2021 GHP "Virtual Meeting" due to COVID19

List of Workshops and Meetings Planned in 2021 and 2022
Meeting title, dates and location and anticipated travel support needs.

- 2022 GHP meeting planned for July 2022, in conjunction with the Pan-GEWEX meeting.

Other Meetings Attended On Behalf of GEWEX or Panel in 2020

- Ali Nazemi attended a number of meeting related to WCRP lighthouse activity, My Climate Risk.
- Dominguez attends the US-RHP and the ANDEX bi-monthly virtual meetings regularly.

Publications during Reporting Period

List of Key Publications

- See individual action reports.

2.4 Global Land/Atmosphere System Study (GLASS)

Full Panel Name (Acronym) : Global Land/Atmosphere System Study Panel
Reporting Period : 01 January - 31 December 2021
Starting Date : N.A.
End Date (when applicable) : N.A.
URL : https://www.gewex.org/panels/global-landatmosphere-system-study-panel/

Membership

Chair(s) and Term Dates : Kirsten Findell, 2019 - Present
Anne Verhoef, 2020 - Present

Members and Term Dates : *Gab Abramowitz, 2008 - Present
Souhail Boussetta, 2018 - Present
Nathaniel Chaney, 2019 - Present
^Paul Dirmeyer, 2000 - Present
^John Edwards, 2014 - Present
Michael Ek, 2009 - Present
Craig Ferguson, 2011 - Present
Samiro Khodayar Pardo, 2019 - Present
*Hyungjun Kim, 2010 - Present
*David Lawrence, 2014 - Present
^Xianhong Meng, 2019 - Present
^Joshua Roundy, 2016 - Present
*Joseph Santanello, 2011 - Present
Gert-Jan Steeneveld, 2021 - 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)

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

List of Panel Goals

Adjust yearly

- Assess the overall breadth of GLASS projects, expand the panel's work in GLASS-relevant areas highlighted by the GEWEX Science Plan: human intervention in the climate system and carbon cycle processes at the land-atmosphere interface.

List of 2 to 3 Key Results

Adjust yearly with respect to goals

- GLAFO: University of Hohenheim LAFO site operational, most of the data available soon (see https://enoha.eu/ddp/dispatch?searchparams=keywords-lafo)
- PLUMBER showed that LSMs can perform much better than they currently do, given the amount of information they are provided with in meteorological forcing data, though ILAMB showed that CMIP6 models perform better than CMIP5 models.
- SoilWat: A framework was developed for quantifying hydrologic effects of soil structure across scales; Global maps of soil water characteristics parameters were produced— by fusing curated data with machine learning and environmental Covariates; A paper involving key SoilWat members and others has been accepted by Nature Reviews Earth & Environment, titled 'Soil hydrology in the Earth system', which highlights that linking soil hydrology and pedology will lead to better understanding of critical zone processes, especially in tropical regions;

Other Science Highlights

Not part of the 2-3 key results

- SoilWat: the parameterisation of soil water stress in LSMs was tested in two papers; A paper was published proposed framework for a *global groundwater modeling and monitoring* system: Opportunities and challenges.

Panel Activities during Reporting Period

List of Panel Activities and Main Result

Summary of Working Groups (Projects) Report

- LoCo's influence on the community was visible through (a) collaborations with modeling and operational centers, and (b) observational advancements planned and/or discussed at NASA, NOAA, DOE, with the AmeriFlux community, and in multiple field campaigns in the US and Europe.
- GLAFO had a successful first year: the observatory at the University of Hohenheim is operational and the GLAFO White Paper has gone through many revisions.
- PLUMBER's substantial efforts on the production of a quality-controlled dataset of flux station data is complete; data are available on modelevaluation.org and the dataset description paper is published.
- ILAMB's assessment of CMIP6 coupled models compared to CMIP5 models shows general and broad improvement in land-related fields. Assessment was used within IPCC AR6 report. (https://www.ilamb.org/CMIP5v6/historical/)

SoilWat renewed its impetus regarding the analysis of their soil parameter MIP (SP-MIP) data (conducted globally with 8 key land surface models). Two manuscripts are being prepared.

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

- New irrigation project (cross-cutting with GHP) began in 2021. Two-day virtual meeting held in November had broad community participation and began the process of identifying the path forward.

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

- PLUMBER: Actively working with individuals in the Fluxnet community to automate delivery of flux tower data, with LSM-focused QC, to modelevaluation.org
- Based on the success of the CLASP (Coupling of Land and Atmospheric Subgrid Parameterizations) project in the US and the international interest CLASP is garnering, we plan to proposed that CLASP become a GLASS project in 2022.
- In 2021 we had initial conversations about bringing carbon more explicitly into the GLASS Panel portfolio of projects. In 2022 we hope to bring in a project related to solar induced chlorophyll fluorescence (SIF).
- SoilWat is preparing a joint discussion with the new carbon-water cycle initiative in GLASS on how SoilWat can contribute.

Science Issues and Collaboration during Reporting Period

Contributions to Developing GEWEX Science and the GEWEX Imperatives.

a. Data Sets

- PLUMBER's flux station dataset is available on modelevaluation.org.
- ILAMB makes a host of relevant datasets available for comparison with model output.
- GLAFO data from the University of Hohenheim LAFO site are being made available.
- SoilWat: Gupta et al., 2021, SoilKsatDB: global database of soil saturated hydraulic conductivity measurements for geoscience applications. Earth System Science Data 13 (4), 1593-1612
- SoilWat: Gupta et al., 2021. Global Prediction of Soil Saturated Hydraulic Conductivity Using Random Forest in a Covariate- Based GeoTransfer Function (CoGTF) Framework, Journal of Advances in Modeling Earth Systems 13 (4), e2020MS002242
- SoilWat: Zhang et al.: Status of the Tibetan Plateau observatory (Tibet-Obs) and a 10-year (2009-2019) surface soil moisture dataset, Earth Syst. Sci. Data, 13, 3075-3102, https://doi.org/10.5194/essd-13-3075-2021, 2021
- SoilWat: Dorigo et al.: The International Soil Moisture Network: serving Earth system science for over a decade, Hydrol. Earth Syst. Sci., https://doi.org/10.5194/hess-2021-2
- SoilWat: Szabo et al.: Updated European hydraulic pedotransfer functions with communicated uncertainties in the predicted variables (euptfv2), Geosci. Model Dev., 14, 151-175, https://doi.org/10.5194/gmd-14-151-2021, 2021.

b. Analysis

- LoCo Cheat Sheets: http://cola.gmu.edu/dirmeyer/Coupling_metrics.html

c. Processes

- ILAMB benchmarking tools help identify process-related sources of model deficiencies.
- GLAFO: targeting turbulence and transport processes in the land-atmosphere system.
- SoilWat: Soil infiltration, surface evaporation, coupled soil water and heat flow, groundwater dynamics, root hydraulics, soil-water-plant-energy interactions

d. Modeling

- ILAMB comparisons help identify model deficiencies and areas needing attention.
- GLAFO: Nested modeling down to LES for process and feedback studies.
- SoilWat: The simulation results of SP-MIP runs are being analysed in terms of the modelled soil moisture and thermal regimes, e.g., in the context of soil moisture indices and drought propagations, and meaningful metrics to assess the thermal regime
- SoilWat: The STEMMUS-SCOPE model, STEMMUS-T&C model has been used to evaluate impacts of soil water/heat dynamics on ecosystem functioning, in terms of water, energy and carbon fluxes. Currently, STEMMUS-SCOPE is running FLUXNET2015 data and will provide inputs for PLUMBER2.

e. Application

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f. Technology Transfer

- GLAFO: Lidar technology for operational measurements of water and temperature profiles from the surface to the lower troposphere.

g. Capacity Building

- SoilWat: Co-organisation of WG meetings with ISMC Soil Thermal Properties WG, Pedotransfer Function WG, Soil Carbon WG, for bridging soil processes and Earth system models.

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?

Inherently, the LoCo paradigm and process-chain captures all three elements of GS1 and describes the connections between reservoirs (SM), fluxes (ET), the PBL, and ultimately clouds and precipitation (extremes). As such Earth's water cycle is comprised of these links and feedbacks and any changes (as posed here) in one will impact the others. LoCo is designed to understand how/why these changes impact the water cycle as a whole, recognizing the interconnectness inherent in reservoirs, fluxes, and precipitation.

SoilWat: The fast reservoirs (lakes, wetlands, soil moisture storage, groundwater storage) on land surfaces over permafrost regions are changing at an accelerating rate. Studies linked to freezing/thawing dynamics of permafrost should be urgently considered. For example,

Yu, L., Fatichi, S., Zeng, Y., and Su, Z.: The role of vadose zone physics in the ecohydrological response of a Tibetan meadow to freeze–thaw cycles, The Cryosphere, 14, 4653–4673, https://doi.org/10.5194/tc-14-4653-2020, 2020

2. Flux exchanges:

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

As mentioned above, the efforts of LoCo and GLAFO are central to understanding these questions from a local process-based perspective. Extending the insights gained from these initiatives will allow us to answer these questions on broader scales.

3. Precipitation Extremes:

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

SoilWat: The improved description of soil processes in LSM/Climate Models will improve the quantification of flux exchanges, which will inevitably improve the estimation of precipitation extremes. For example, afternoon rain falls preferentially over dry soils, particularly over semi-arid regions, where surface fluxes are sensitive to soil moisture and convective events are frequent.

Indeed, all of the GLASS projects can contribute to improved representation and understanding of precipitation, especially in tackling some of the long-standing difficulties related to modeling precipitation extremes.

Goal # 2 (GS2): Quantify the inter-relationships between Earth's energy, water and carbon cycles to advance our understanding of the system and our ability to predict it across scales:

1. Forcing-feedback understanding:

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

The realistic consideration of soil processes in climate models will help improve the forcing-feedback understanding. SoilWat is making various efforts in terms of representing soil processes in climate models, for example: 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 oftenly omitted in climate model while its importance for affecting land surface flux exchanges are non-trivial. There are also ongoing efforts relating to plant water stress and the role of soil hydraulics in this.

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)?

GLAFO and LoCo are at the core of this question as well, in that LoCo metrics and science are specifically focused on quantifying the impact of surface fluxes on the PBL (and vice-versa), and GLAFO is focused on observing these processes at very high spatial and temporal resolutions. LoCo has been a leader in demonstrating these feedbacks, as well as identifying the need for better observations particularly of the PBL. As LoCo considers how to expand beyong the 1-D paradigm, questions of horizontal scale and transport in the PBL will become important as well.

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 and the ABL-free atmosphere exchanges, due to its unique land surface process behaviour, and its high altitude.

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?

The link between land surface states/fluxes (soil moisture, groundwater) and the large-scale circulations has been progressing in past decades, for example, the fully coupled Earth System Modelling (& Data Assimilation), FLUXNET, and many others. Nevertheless, the existing Earth Observation data are not yet sufficient to enable the observation-based quantification of such interactions. A vivid example is the Tibetan Plateau, where the SMOS/SMAP soil moisture 'daily'

products are only available for those summer months, limiting the study on the link between soil moisture and circulation. There is perhaps a scope here to link with the GEWEX Central Asia effort, as we are dealing here with vast, land-locked, semi-arid areas where moisture recycling is an important phenomenon.

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?

By developing and employing integrated metrics to confront our models, facilitated by improved observations (for both evaluation and assimilation).
SoilWat aims to improve representation of soil processes in climate models, which will ultimately improve the understanding and prediction of land-atmosphere interactions. The direction we are pushing is to realisticly represent the coupling mechanisms among water, energy and carbon cycles in the soil and above ground.

Within SoilWat we are discussing a new effort looking at the cascading effect of different soil maps (and the PTFs used to translate these maps into soil hydraulic and thermal parameters) → spatio-temporal distribution of soil moisture contents, surface temperatures & evaporative fraction → convective cloud-forming processes → feedback on the land surface via cloudiness and precipitation. It seems there is an emerging potential to have a cross-cutting group closely co-coordinated with the LoCo and CLASP projects. We also envisage that it would cut across different panels (e.g. including GASS and GHP).

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?

Since anthropogenic forcing is represented by elevated atmospheric CO2 concentrations, this point is largely linked to photosynthesis, and the sensitivity of stomatal conductance to CO2 concentrations, 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?

There are direct connections of LoCo with irrigation practices, groundwater withdrawl, land use change as the impacts of these surface changes are felt in the atmosphere (PBL, hence L-A interactions).

Also relevant is that these water management influences create heterogeneity at the surface that needs to be better captured in models at the native scales of heterogeneity. The CPT/CLASP project is directly addressing this in GCM world, but the questions are broader and impact NWP, mesoscale, LES

as well. Understanding the role of heterogeneity in L-A and atmospheric circulations is an active topic of research.

The irrigation project (cross-cutting with GHP) is also highly relevant here.

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 modify significantly the water cycle, but also local climate systems (e.g., local advection effect, more afternoon rain over dry soils). Furthermore, changes in land use land cover will change the soil hydraulic and thermal properties, which will in turn impact the land surface water, energy and carbon fluxes.

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?

The new GLASS initiatives related to irrigation (Irrigation Cross-cut) and surface heterogeneity (CLASP) will be instrumental in advancing our understanding of these issues.

Other Key Science Questions

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

- How do PTF/soil properties and detailed soil processes impact land surface fluxes/states. Can this be assessed using intelligent, physically meaningful metrics?
- What are the roles of soil-root-plant hydraulics and soil-groundwater interactions in affecting land-atmosphere interactions?
- How do water, energy, carbon fluxes within the soil and vegetation couple, how do they respond to climate change, and what is their feedbacks to land-atmosphere interactions?
- How do soil respiration dynamics couple with soil moisture and heat dynamics (e.g., in thawing permafrost), and how do these interactions be linked to a broader discussion of soil component of GHG emissions (N2O, CH4)?

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.

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

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

- SoilWat will potentially contribute to the evaluation/assessment of crop/agriculture water productivitiy, as such contributing to 'Water for the Food Baskets', 'farm to fork'.
- Outside bodies: the SoilWat initiative is intricately linked to the activities by the International Soil Modelling Consortium (ISMC):https://soil-modeling.org

Workshops and Meetings

List of Workshops and Meetings Held in 2021

Meeting title, dates and location.

- Irrigation Crosscut workshop, Nov. 2021, Virtual
- L-A sessions convened at AGU20 and AMS21, AGU 21

- ET Crosscut Workshop, February 2021, Virtual
- CLASP Meetings, February and April 2021, Virtual
- ISMC-SoilWat Breakout "Soil Thermal Properties Working Group Meetings" (June 8th, July 29th), see link: https://soil-modeling.org/science-panels/working-groups/thermal-properties/wg-meetings
- ISMC-SoilWat Breakout "Pedotransfer Function Working Group meeting" (June 10th), see link: https://soil-modeling.org/science-panels/working-groups/pedotransfer-functions-and-land-surface-parameterization-1/minutes-of-the-wg-meetings
- ISMC-SoilWat Breakout "Global soil carbon modelling" (monthly), zoom
- ISMC-SoilWat Breakout meeting at EGU (April 2021), online

List of Workshops and Meetings Planned in 2022 and 2023

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

- L-A sessions convened at AGU22 and AMS23
- L-A Sessions at Pan-GASS, July 2022, Monterey
- Strong GLASS participation in The Land Surface Modeling Summit, Oxford, UK, Sept. 2022.
- LIAISE First Science Conference and GEWEX's Evapotranspiration Crosscutting Project Workshop (28-30 November 2022, Lleida, Spain). Travel support may be required.

Other Meetings Attended On Behalf of GEWEX or Panel in 2021

- Strong GLASS participation (invited talks by GLASS members Findell and Santanello) in the AmeriFlux Land-Atmosphere Workshop, June 2021, Virtual

Publications during Reporting Period

List of Key Publications

- Many LoCo-relevant publications listed in LoCo report.
- Ukkola, A.M., G. Abramowitz and M.G. De Kauwe, 2022: A flux tower dataset tailored for land model evaluation. *Earth Syst. Sci. Data*, 14, 449–461, https://doi.org/10.5194/essd-14-449-2022.
- Collier, N., F. Hoffman, D.M. Lawrence and C. Koven, 2022: Leveraging community consensus to assess subjective benchmarking choices. Submitted.
- Hardouin, L., C. Delire, B. Decharme, D.M. Lawrence, J. Nabel, V. Brovkin, N. Collier, R. Fisher, F.M. Hoffman, C.D. Koven, R. Seferian and T. Stacke, 2022: Uncertainty in land carbon budget simulated by terrestrial biosphere models: the role of atmospheric forcing. Submitted.
- Wulfmeyer, V., and A. Behrendt, 2021: Raman Lidar for Water-Vapor and Temperature Profiling. In: *Handbook of Atmospheric Measurements* (T. Foken, ed.). Switzerland, Springer Nature. https://doi.org/10.1007/978-3-030-52171-4_25.
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- Wang, Y., Y. Zeng, L. Yu, P. Yang, C. Van der Tol, Q. Yu, X. Lü, H. Cai and Z. Su, 2021: Integrated modeling of canopy photosynthesis, fluorescence, and the transfer of energy, mass, and momentum in the soil–plant–atmosphere continuum (STEMMUS–SCOPE v1.0.0). *Geosci. Model Dev*., 14, 1379–1407, https://doi.org/10.5194/gmd-14-1379-2021.
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Annex 1: List of Participants

GEWEX SCIENTIFIC STEERING GROUP

Jan Polcher, Co-Chair
Laboratoire de Météorologie Dynamique du CNRS
Paris, France
Email: jan.polcher@lmd.jussieu.fr

Xubin Zeng, Co-Chair
University of Arizona
Tucson, AZ, USA
Email: xubin@email.arizona.edu

Myoung-Hwan Ahn
EWHA Womans University
Seoul, Republic of Korea
Email: terryahn65@ewha.ac.kr

Gianpaolo Balsamo
European Centre for Medium-range Weather (ECMWF)
Reading, United Kingdom
Email: gianpaolo.balsamo@ecmwf

Michael Bosilovich
Global Modeling and Assimilation Office
National Aeronautics and Space Administration (NASA)
Greenbelt, MD, USA
Email: michael.bosilovich@nasa.gov

Gabi Hegerl *(Remote)*
University of Edinburgh
Edinburgh, Scotland
Email: gabi.hegerl@ed.ac.uk

Christian Jakob *(Remote)*
Monash University
Clayton (VIC), Australia
Email: christian.jakob@monash.edu

Benjamin Lamptey
Suez Consulting Company
Akra, Ghana
Email: bllamptey@gmail.com

L. Ruby Leung
Pacific Northwest National Laboratory (PNNL)
Richland, WA, USA
Email: ruby.leung@pnnl.gov

Maria Piles Guillem
Universitat de València
València, Spain
Email: Maria.piles@uv.es

Germán Poveda
Universidad Nacional de Colombia
Medellín, Colombia
Email: gpoveda@unal.edu.co

Graeme Stephens
Center for Climate Sciences
Jet Propulsion Laboratory (JPL)
Pasadena, CA, USA
Email: graeme.stephens@jpl.nasa.gov

Bob Su
University of Twente
Enschede, The Netherlands
Email: z.su@utwente.nl

GEWEX PANEL REPRESENTATIVES

Sandrine Bony
GASS Co-Chair
CNRS, LMD/IPSL, Sorbonne University
Paris, France
Email: Sandrine.bony@lmd.jussieu.fr

Francina Dominquez
GHP Co-Chair
Department of Atmospheric Sciences
University of Illinois
Champaign, IL, USA
Email: francina@illinois.edu

Kirsten Findell
GLASS Co-Chair
Geophysical Fluid Dynamics Laboratory
Princeton, NJ, USA
Email: kirsten.findell@noaa.gov

Daniel Klocke
GASS Co-Chair
Hans Ertel Center for Weather Research
Deutscher Wetterdienst
Offenbach, Germany
Email: daniel.klocke@dwd.de

Tristan L'Ecuyer
GDAP Co-Chair
University of Wisconsin
Madison, WI, USA
Email: tlecuyer@wisc.edu

Hirohiko Masunaga
Incoming GDAP Co-Chair
Nagoya University
Nagoya, Japan
Email: masunaga@hyarc.nagoya-u.ac.jp

Ali Nazemi
GHP Co-Chair
Department of Building, Civil and Environmental Engineering Concordia University
Montreal, QC, Canada

Rémy Roca
GDAP Co-Chair
Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS)
Toulouse, France
Email: remy.roca@legos.obs-mip.fr

Anne Verhoef
GLASS Co-chair
University of Reading
Reading, Berkshire, UK
Email: a.verhoef@reading.ac.uk

WCRP REPRESENTATIVES

Hindumathi Palanishamy
WCRP Secretariat
World Climate Research Programme
Geneva, Switzerland
Email: hpalanisamy@wmo.int

Mike Sparrow
WCRP Secretariat
World Climate Research Programme
Geneva, Switzerland
Email: msparrow@wmo.int

Detlef Stammer
Chair Joint Scientific Committee
World Climate Research Programme
Center for Earth System Research
Hamburg, Germany
Email: detlef.stammer@uni-hamburg.de

AGENCY DELEGATES AND OTHER INVITEES

Carlo Buontempo
C3S/ECMWF
Reading, United Kingdom
Email: C3S/ECMWF

Leila Carvalho
CLIVAR/GEWEX Monsoon Panel
Earth Research Institute
Santa Barbara, CA, U.S.A.
Email: leila@eri.ucsb.edu

Alexander Da Silva
U.S. Global Change Research Program (USGCRP)/University of Connecticut

Jared Entin *(Remote)*
National Aeronautics and Space Administration (NASA)
Greenbelt, MD, USA
Email: jared.k.entin@nasa.gov

Diego Fernandez *(Remote)*
European Space Agency (ESA/ESRIN)
Frascati, Italy
Email: Diego.Fernandez@esa.int

Carla Gulizia
RFP South America
University of Buenos Aires & CONICET
Buenos Aires, Argentian
Email: carla.gulizia@gmail.com

Jin Huang
NOAA Climate Program Office
Silver Spring, MD, USA
Email: jin.huang@noaa.gov

Misako Kachi *(Remote)*
Japan Aerospace Exploration Agency (JAXA)
Tsukuba–Ibaraki, Japan
Email: kachi.misako@jaxa.jp

Jürg Luterbacher
World Meteorological Organization (WMO)
Geneve, France
Email: jluterbacher@wmo.int

Catherine Michaut
Laboratoire de Météorologie Dynamique (LMD)
Paris, France
Email: catherine.michaut@ipsl.fr

Felix Perosanz *(Remote)*
Centre national d'études spatiales (CNES)
Paris, France
Email: felix.perosanz@cnes.fr

Jeff Privette *(Remote)*
National Oceanic and Atmospheric
Administration (NOAA)
Asheville, NC, U.S.A.
Email: jeff.privette@noaa.gov

Paolo Ruti *(Remote)*
European Organisation for the Exploitation
of Meteorological Satellites (EUMETSAT)
Darmstads, Germay
Email: Paolo.Ruti@eumetsat.int

Jose Santos *(Remote)*
International CLIVAR Project Office
Qingdao, China
Email: icpo@clivar.org

Steven Sherwood
LHA Safe Landing Climates/
University of New South Wales
Sydney, Australia
Email: s.sherwood@unsw.edu.au

Seok-Woo Son *(Remote)*
SPARC
Seoul National University
Seoul, South Korea
Email: seokwooson@snu.ac.kr

Peter van Oevelen
International GEWEX Project Office
Washington, DC, USA
Email: gewex@gewex.org

Fernande Vervoort
International GEWEX Project Office
Washington, DC, USA
Email: gewex@gewex.org

Annex 2: Agendas GEWEX SSG-34A&B

Agenda GEWEX SSG 34A, Paris, France 3 – 5 May 2022
Day 1 Strategic Planning

08:15 – 08:30	Welcome	Jan Polcher, Xubin Zeng and Peter van Oevelen
08:30 – 10:00	GLASS	Kirsten Findell and Anne Verhoef
10:00 – 10:30	*Break*	
10:30 – 12:00	GASS	Sandrine Bony and Daniel Klocke
12:00 – 13:30	*Lunch*	
13:30 – 15:00	GDAP	Rémy Roca and Tristan L'Ecuyer
15:00 – 15:30	*Break*	
15:30 – 17:00	GHP	Francina Dominguez and Ali Nazemi (Remote)
17:00 – 17:30	Wrap Up	Peter van Oevelen
20:00 –	Group Dinner in Paris, Bouillon Racine, rue Racine, Paris, FR 75006	

Day 2 WCRP Light House activities, New CPs and Meeting Planning

08:30 – 09:00	Safe Landing Climates	Gabi Hegerl, Hyungyun Kim
09:00 – 09:30	Digital Earth	Christian Jakob, Andreas Prein
09:30 – 10:00	Explaining and Predicting	Kirsten Findell
10:00 – 10:30	*Break*	
10:30 – 11:00	My Climate Risk	Ali Nazemi, Paola Arias
11:00 – 11:30	SSG-34B Planing	Xubin Zeng and Jan Polcher
11:30 – 12:00	Regional Information for Society (RiFS)	Peter van Oevelen, Ali Nazemi
12:00 – 12:30	Earth System Modelling and Observations (ESMO)	Remy Roca
12:30 – 14:00	*Lunch*	
14:00 – 14:30	WCRP Secretariat Update	Hindumathi Palanisamy and Mike Sparrow
14:30 – 15:00	Pan-GASS update	Daniel Klocke
15:00 – 15:30	WCRP Academy	Mike Bosilovich, Qingyun Dian
15:30 – 16:00	*Break*	
16:00 – 17:00	PAN-GEWEX Planning I	Xubin Zeng and Jan Polcher
17:00 – 17:30	Wrap Up	Peter van Oevelen

Day 3 Strategic Planning continued

08:30 – 09:30	Pan-GEWEX Planning II	Jan, Xubin and Peter
09:30 – 10:00	30-years GEWEX History –	Graeme Stephens
10:00 – 10:30	*Break*	
10:30 – 11:00	WCRP Hydrology	Jan Polcher
11:00 – 11:30	Global Precipitation Experiment (GPEX)	Xubin Zeng
11:30 – 12:00	Cycles	Jan Polcher
12:00 – 13:30	*Lunch*	
13:30 – 15:00	GEWEX Strategic Direction and Activities	Jan Polcher and Xubin Zeng
15:00 – 15:30	*Break*	
15:30 – 16:00	Any Other Topics	Jan Polcher, Xubin Zeng and Peter van Oevelen
16:00 – 17:00	Summary Action Items and Recommendations	Peter van Oevelen
17:00 – 17:30	Wrap Up	Peter van Oevelen

Agenda GEWEX SSG-34B, Monterey, CA, USA 26–27 July 2022

Day 1 Tuesday 26 July 2022

09:00 – 09:15	Intro and Welcome	Jan Polcher, Xubin Zeng and Peter van Oevelen
09:15 – 10:30	Space Agency Roundtable	Xubin Zeng *(moderator)*
10:30 – 11:00	*Break*	
11:00 – 12:30	How to Increase Engagement in WCRP *(Moderated Panel discussion)*	Panelist: Carla Gulizia and Francina Dominguez Challenger: Benjamin Lamptey
12:30 – 14:00	*Lunch*	
14:00 – 14:30	GDAP Science Presentation	Tristan L'Ecuyer / Hiro Masanuga
14:30 – 15:00	GHP Science Presentation	Francina Dominguez / Ali Nazemi
15:00 – 15:30	GASS Science Presentation	Sandrine Bony / Daniel Klocke
15:30 – 16:00	GLASS Science Presentation	Kirsten Findell / Anne Verhoef
16:00 – 16:30	*Break*	
16:30 – 17:00	CLIVAR/GEWEX Monsoon Panel Presentation	Leila Carvalho
17:00 – 17:30	Recognition Graeme Stephens	Jan Polcher, Xubin Zeng and Peter van Oevelen
18:45 –	Banquet together with participants of the 3rd Pan-GASS Meeting	

Day 2 Wednesday 27 July 2022

09:00 – 09:30	World Meteorological Organisation (WMO)	Jürg Luterbacher
09:30 – 10:00	World Climate Research Programme (WCRP)	Detlef Stammer
10:00 – 10:30	WCRP/WMO Program interactions	Jan Polcher / Xubin Zeng *(Moderators)*
10:30 – 11:00	*Break*	
11:00 – 12:30	GEWEX SSG Business • GEWEX Ambassadorship • GEWEX Lifetime Achievement • New GEWEX SSG Nominations • AOB	Peter van Oevelen *(Moderator)*
12:30 – 14:00	*Lunch*	

Annex 3: Rapporteur Reports on GEWEX Panels

Rapporteurs report for the 34th GEWEX SSG Meeting

Panel: Global Atmospheric System Studies (GASS)
Rapporteur(s): Ruby Leung, Myoung Hwan Ahn and Christian Jakob

Adherence to GEWEX' and Panel's objective(s)

The overall objective of the GASS panel is to improve the understanding of physical processes in the atmosphere and their coupling to atmospheric dynamics.

To achieve its objective, 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.

Achievement of annual goals for this reporting period

During this reporting period, the GASS panel activities include 5 projects at various phases, all related to the top three errors identified in the WGNE Systematic Error Survey Results Summary. Noticeable progress has been made by the projects towards their goals.

The GASS Panel, led by Sandrine Bony and Daniel Klocke, organized the Pan-GASS conference with > 180 abstracts on various topics. The conference was extremely successful and featured high-quality science and well-prepared presentations.

The GASS Panel has demonstrated successful community building through sharing of knowledge, expertise, data, and tools.

Major accomplishments and results in reporting period

Ending, Ongoing, and Joining Projects

- COORDE (COnstraining ORographic Drag Effects): This is an ending project with the goal to understand the effects of resolved and parameterized orographic drag. A key activity of COORDE to compare and validate the parameterized orographic drag parameterizations used in operational models is summarized by van Niekerk et al. (2020), showing underestimation of total orographic gravity wave drag over land in most models.
- Demistify: This is an ending project that aims at understanding and improving modeling and forecasting of radiation fog. A key activity of the project to intercompare single column models and large-eddy simulation models for a radiation fog case study using the Local and Non-Local Fog Experiment (LANFEX) field campaign data is summarized in Boutle et al. (2022).
- GABLS-4 (GEWEX Atmospheric Boundary Layer Study): This ending project led by Eric Bazile studied stable boundary layers with surface interaction on the Antarctic plateau. Taking advantage of observations from an instrumented site at Dome C, several papers have been published and an overview paper is in preparation.

- LS4P (Impact of land temperature and snowpack initialization on S2S prediction: Led by Yongkang Xue, this ongoing project addresses two questions related to the impact of initialization of large-scale land temperature and snowpack in climate models on S2S prediction and the relative role and uncertainties in land processes versus sea surface temperature in S2S prediction. Phase I of this project is summarized in several papers including an overview paper by Xue et al. (2022).
- DCP (Diurnal and sub-diurnal precipitation project): Led by Shaocheng Xie, this ongoing project aims to understand what processes control the diurnal and sub-diurnal variation of precipitation in different climate regimes for improving parameterization of convection in GCMs. A paper was published on comparison and evaluation of multi-year single column model runs, while ongoing studies have a focus on GCM, cloud resolving models, and large-eddy simulation models.
- GAP (GEWEX Aerosol Precipitation Initiative): Led by Philip Stier and Sue Van Heever, the goal of this project, which is in the process of joining GASS, is to better understand the multiple ways in which aerosols interact with precipitation and their implications for climate.
- UTCC-PROES (Process Evaluation Study on Upper Tropospheric Clouds and COnvection): Led by Claudia Stubenrauch, this crosscutting project between GDAP and GASS aims to better understand the link between convection and the properties of upper-tropospheric anvils.

Third Pan-GASS Conference

The GASS Panel organized the 3rd Pan-GASS conference on "Understanding and Modeling Atmospheric Processes" on July 25-29, 2022, in Monterey, CA. Major themes of the conference include: (1) organization of shallow and deep convection; (2) surface-atmosphere interactions and the boundary layer; (3) cloud systems and associated processes (microphysics, physics, dynamics, radiation); (4) global km-scale modeling and digital twins of the Earth system. Over 180 abstracts were submitted and presented in oral and poster sessions. The conference also included 11 breakout sessions organized by the GASS projects and research topics on potential new projects.

Arisen or noted science issues

None

Emerging Science

The GASS Panel developed an overarching science question to guide its future activities: How do the micro to meso scale atmospheric processes control global water and energy exchanges? This overarching question will be addressed by answering two subquestions: (1) What controls cloud phase and precipitation; and (2) What controls mesoscale organization?

Future plans

GASS will help to address the emerging science questions through the following activities:

➨ **Coordinating projects/activities:**

- Daily cycle precipitation (DCP)
- Aerosols and precipitation (GAP)
- Upper tropospheric clouds (UTCC)
- Land surface temperature, snowpack and precipitation (LS4P)
- Mesoscale organization of shallow convection (EUREC^{4}A)
- Mesoscale organization of deep convection

- Cold air outbreaks (COMBLE+)
- Convective momentum transport and its impact on the tropical circulation (Friction)
- Air-sea coupling
- Global cloud resolving model simulations (DYAMOND)
- Coupled models nudging

- **Sharing information and facilitating access to relevant model outputs and observations**: e.g., how-to's, hackathons, seminars
- **Sharing process-oriented diagnostics and codes:** e.g., MCS tracking
- **Organizing workshops that bridges expertises and communities around key questions**
- **Connecting to other WCRP partners:** e.g., GDAP/GLASS/GHP, CFMIP, WGNE

Recommendations to Panel

The rapporteurs are very impressed by the efforts of the GASS Panel and the leadership of two co-chairs. The emerging science questions identified by the Panel are critical to achieving the goal of GASS to improve understanding and modeling of physical processes in the atmosphere and their coupling to atmospheric dynamics. GASS could consider augmenting activities in their future plan to address the following needs or opportunities:

- Connect understanding of physical processes to regional and global energy and water cycles?
  - e.g. uncertainty in energy/water budgets due to uncertainty in observing/modeling various physical processes
  - e.g. connections of various physical processes in the energy/water cycles
- Improve connections/collaborations between different but related communities
  - Weather - climate
  - Land - ocean
  - Mid-latitude - tropics
  - Extremes - mean/variability
- Address certain gaps in research areas:
  - Aerosols and aerosol-cloud interactions
  - Waves: convectively coupled equatorial waves (MJO, Kelvin waves, …), gravity waves
  - Weather extremes (e.g., different types of storms)
  - Processes at the interface
  - Predictability

Considerations for SSG

SSG could consider synthesizing some overlapping/related ideas being considered for new projects to yield larger impacts. SSG could also consider ways to broaden participation from the global south:

- Many topics such as mesoscale organized convection should be of interest to scientists in Africa and South America
- Consider new project ideas that may be of broader interest (e.g., weather extremes, convection over land, prediction and predictability)
- Start entraining scientists at the stage of developing the new projects to incorporate ideas and encourage participation

- Consider contributions such as observation data, analysis of model simulations

Additional Remarks

The various GEWEX meetings in Monterey, CA were very successful in promoting communications and collaborations across panels and among different research groups and individual scientists and building communities with shared interests. We want to express our appreciations to the GEWEX SSG co-chairs, the panel co-chairs, and the staff of IPO.

Rapporteurs report for the 33rd GEWEX SSG Meeting

Panel: GEWEX Data and Analysis Panel (GDAP)
Rapporteur(s): Maria Piles, Graeme Stephens

Adherence to GEWEX and Panel's objective(s)

GDAP has evolved its vision to center on global energy and water datasets (i.e., satellite) to support science questions; the focus is to provide expertise in global flux datasets and inform the community of their strengths and limitations, uncertainties, and best practices for using them (tied to science applications)
GDAP appropriately continues to evolve its objectives that in turn are centrally important to GEWEX's new goals. It has three main activities, surface network stewardship, assessment, and projects.

Achievement of annual goals for this reporting period

The pandemic has slowed progress on their different initiatives, but they are regaining momentum and after their meeting in Bern (26–30 Setember 2022) and they'll be well positioned to take on new projects.

- Surface networks: BSRN surface network confirmed as a GCOS recognized reference network, liaising with the remote sensing community to serve as a long way reference standard. No link or updates from ISMN and GPCC networks.
- Projects:
  - Integrated Product project finalized.
  - Project to support cloud science with an advanced dataset: Cloud+. Effort to generate calibrated, gridded Level 1 radiances from common channels on modern geostationary satellites. Level 2 cloud, aerosol, radiative flux, and precipitation products to follow. How to make data available has been noted as an issue.
- Assessments:
  - Joint IPWG/GEWEX precipitation report completed. This precipitation assessment has been long needed and is excellent.
  - Water vapor Phase 2: making good progress, journal special issue published.
  - An assessment on how well we understand EEI and its variability is ongoing - a workshop is planned next spring that may lead to a first set of publications of the key results.

Major accomplishments and results in reporting period

- The Baseline Surface Radiation Network (BSRN) is being used as a reference for Copernicus Cal/Val needs. Strong connection with GDAP.
- Great coordination with IPWG for consolidation of the precipitation report.
- First prototypes of Cloud+ produced. GDAP expects and Cloud+ dataset to be a centerpiece of their activities in the coming years.
- The new EEI assessment activity is thriving - a workshop is planned next spring that may lead to a first set of publications of the key results.

Arisen or noted science issues

Panel activities at present are mainly focused on radiation and ocean-atmosphere studies, while land is not being covered. The appointment of panel member(s) with land expertise is encouraged to promote that GDAP covers observational data over land as well.

Emerging Science

There are a number of science areas that are ready to emerge especially to be linked to ISCCP- NG. One in particular is that of convection tracking, convection typing, and lifetime characterization as called out above. GDAP would be the ideal body to advance this topic by first assessing the various activities and data records that have blossomed over the past few years in preparation for application of these tools to the emerging ISCCP-NG 1b.
The panel speed dating was inspirational, with one new activity starting to take shape with each panel:

- GHP: supply subsets of global precipitation datasets for each of their Regional Hydroclimate Projects; investigate extreme precipitation and how to make satellite datasets more suitable for studying extremes as they're currently not really designed for this purpose.
- GLASS: Organization of a joint GDAP-GLASS workshop in early 2023. Potential exploitation of Level 1 radiances from modern geostationary satellites (Cloud+) with high revisit and 5-km to investigate different aspects of modeling land-atmosphere interactions at high spatial scales.
- GASS: apply km-scale global model simulations to emulate satellite observations and facilitate model evaluation/improvement

Future plans

H. Masunaga appointed as new co-chair in lieu of R. Roca. Three new member panels have been appointed, connecting to space agencies. Upcoming panel meeting in Bern (26–30 September 2022) will be central to shaping future activities.

Recommendations to Panel

- The projects at present seem to be mostly data centric and we would suggest GDAP define projects, that could be long standing and more connected to science. This could include, for e.g., regular updates on the energy balance and EEI as it is now doing analogous the regularly produced state of climate publication. Perhaps it could include some degree of ownership of new diagnostic tools that might, for e.g., emerge from ongoing assessment studies such as the soon the be conducted convection-based data product review/assessment and convection object property method assessment.
- In addition to its plans, GDAP should ‘sponsor’ workshops on ISSCP-NG and co-sponsor a workshop on Convection object analysis – the latter could be co-formed with for example the AOS management who seek to do something similar.
- Panels interactions: Yunyan Zhang is the liaison with GLASS. Perhaps it would be good to have a liaison with GLASS and GDAP as well.
- Harmonized in-situ data networks are fundamental for satellite validation and calibration needs. In this regard, it is recommended that GDAP coordinates with GHP and GLASS to make sure there is a GEWEX link with existing harmonized observational networks to gain insight about their current status and existing gaps in the context of present/future EO missions and observational capabilities (e.g., ISMN, GPCC).
- Communication with GCOS is lost. Try to reconnect?

- There is a great opportunity to connect the Cloud+ work to the evaluation and assessment of the emerging new generation of global km-scale models (cross w/Digital Earth Lighthouse activity).
- Communicate main results conveyed in detailed WCRP reports in scientific journals that point to the report. Visibility & Outreach.

Considerations for SSG

SSG meeting format: apart from the highlights from the Panels, perhaps also include in the agenda science presentations from one panel member or SSG member relevant to current GEWEX activities Pan-GEWEX meeting has been very informative and beneficial to gain more understanding of the natures of the various activities within GHP and GLASS. It is suggested that SSG members try to participate in future GEWEX Panel meetings.

Additional Remarks

Regarding consistency of satellite datasets:

- Consistent data records of single variables are already being produced (e.g., ESA Climate Change Initiative). Beyond, optimization activities across several variables by enforcing global conservation laws and considering the uncertainty information that comes along with the data products -as done by GDAP on EEI- are very promising.
- Such approach could potentially be useful to other compartments, e.g., to ensure consistency in hydrological variables such as land surface water fluxes (including evaporation, transpiration, and runoff) and storages (including soil moisture, vegetation, and groundwater) for instance. Diagnostic tool for Digital Earth?

Rapporteurs report for the Monterey GEWEX SSG Meeting 34B

Panel: GEWEX Hydroclimatology Panel (GHP)
Rapporteur(s): Michael Bosilovich and Benjamin Lamptey

Adherence to GEWEX and Panel's objective(s)

The Panel continues 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, in line with the panel's objectives.

Achievement of annual goals for this reporting period

GHP is managing many projects directed at the stated annual goals. Most are making notable progress, and some are sunsetting (e.g., OZEWEX). GHP has reported numerous publications, workshops and meetings all aimed at progressing the panel's and GEWEX's goals, e.g., PannEx special issue and 2nd CC-ET workshop among others). New projects are under development (uch as a US-RHP) utilizing the best practices and lessons learned from current successful projects (e.g., GWF and Baltex).

Major accomplishments and results in reporting period

Baltex continues to produce, including but not limited to, 30 papers in a special issue, a Conference, and summer/winter schools. Their fact sheet document published Sept 2021 is connecting scientists with stakeholders on climate change. The plan to continue into the future, conducting internal assessments and looking for gaps and new challenges.

GWF - GWF Observatories, 76 sites, funded through 2029. Had an annual open science meeting May 22, Next will be in May 2023. GWF has a significant effort linking western science with indigenous knowledge. They have Mentoring and Career Development activities across the program. The GWF Planetary Water Predictive Initiative is applying Canadian models globally, working closely with WMO and UNESCO. GWF has secured funding to maintain its observatories until 2029.

GPCC – New data added (Brazil, Canada, Poland Iran, Kenya) and two sets of correction factors available. V2022 to be available Aug 2022. AI is being developed for quality control routines.

GRDC – data policy updated and now included online, and new data portal enhancing the dissemination of data. Data User Policy integrated into data request. Supports UNESCO IHP and Friends-Water Community; GCOS/TCOP

ANDEX - Implementation plan submitted and accepted, and lots of progress and activities including an ANDEX White Book

Arisen or noted science issues

Dr. Looser, head of GRDC, is on his last retirement extension, and is transitioning his responsibilities

Emerging Science

GHP Speed dating activity has led to a number of potential new work to connect panels. With GLASS, there may be potential for a CC on floods (currently proposed), and may complement existing CCs on ET and Irrigation. GASS may have connections through the diurnal cycle, and benchmarking precipitation products across scales (which was also a topic of discussion with GDAP).

There are also some developing discussions on regional budgets and can connect the RHPs. The global project of Prof. L'Ecuyer, GDAP's co-chair, will include a regional component which requires transport terms. A liason with GDAP is under consideration. Ultimately regional budgets also need input from local experts, which would require collaborations with the RHPs.

Future plans

A new Central Asia RHP is currently being formulated. HyMex-2 is also taking shape. A US based RHP has been having routine meetings with a strategic plan under development. Likewise, Asian Precipitaiton Experimentss (AsiaPEX), the Third Pole Environment-Water Sustainability (TPE-WS).

Recommendations to Panel

The panel will benefit from a resource on institutional knowledge to maintain some consistency as members and leaders rotate in and out. In consideration is to develop a fact sheet as a living document. In addition, a brief summary of each project with one or two sentence summary and expanded acronyms to communicate the status and main objective of the vast array of research projects in the panel would make an excellent update to the GHP WWW site.

Considerations for SSG

Prof. Van Oevelen, Director of IGPO, is considering a RHP Conference with Baltex as lead. This discussion should continue and develop.

Additional Remarks

Panel: Global Land/Atmosphere System Study (GLASS)
Rapporteur(s): Bob Su and Gianpaolo Balsamo

Adherence to GEWEX and Panel's objective(s)

The overall objectives of the GLASS panel are:

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

(We suggest changing 'encouragement of' to 'to advance' in first objective)

Achievement of annual goals for this reporting period

The GLASS panel has expanded their work in relevant areas highlighted by the GEWEX Science Plan: human intervention in the climate system and carbon cycle processes at the land-atmosphere interface.

Major accomplishments and results in reporting period

- GLAFO: University of Hohenheim LAFO site operational. Based on Volker Wulfmeyer's presentation, it can be expected that detailed analysis of the data may lead to major paradigm shifts in advancing parameterization of land-atmosphere interactions.
- ILAMB showed that CMIP6 models perform better than CMIP5 models and it has been used in guiding the development of the new models (e.g., European Center for Land (ECLand): an ECMWF land surface modelling platform). Assessment was used within IPCC AR6 report.
- PLUMBER showed that LSMs can perform much better than they currently do, given the amount of information they are provided with in meteorological forcing data. The two projects ILAMB and PLUMBER are highly appreciated by the wider community.
- SoilWat:
  - A framework was developed for quantifying hydrologic effects of soil structure across scales;
  - Global maps of soil water characteristics parameters were produced by fusing curated data with machine learning and environmental covariates;
  - A paper involving key SoilWat members and others has been accepted by Nature Reviews Earth & Environment, titled 'Soil hydrology in the Earth system', which highlights that linking soil hydrology and pedology will lead to better understanding of critical zone processes, especially in tropical regions.

Arisen or noted science issues

Action & discussion points taken forward from meeting with Rapporteurs (June 2022) and discussed at pan-GEWEX (July 2022).

- Seamless GEWEX-GLASS links to **Space Missions**
  - Models process representation for data assimilation and with a focus on observables: SIF (SIF-MIP), Vegetation Optical Depth (VOD), optical spectra, brightness temperature.

- Modelling that caters for Observation System Simulation Experiments (OSSEs), see examples presented by Bob Su)

- Importance of **Carbon Cycle**:
  - link to water cycle (SIF-MIP), uncertainty in ET, don't decouple from carbon cycle. Gross Primary Production (GPP) gives much better indication of accuracy of water stress
  - carbon monitoring Paris agreement - Land Use / Land Cover (LULC) changes and carbon sequestration can be addressed if carbon processes are included in current and future Land Surface Models)
- Approach model improvements/benchmarking with **stakeholders** in mind (model products, metrics) (see example of ECLand by ECMWF)
- Cryosphere:
  - permafrost/snow processes, glaciers [GEWEX Central Asia initiative; GHP (Canada); WCRP (CliC)]
  - Snow-MIP: led by Rasmussen NCAR?
- (We feel these latter aspects should be strengthened by the GLASS panel)

Emerging Science

Km-scale representation of land-atmosphere interactions and shallow and deep convection and cloud systems (inc. heavy precipitation) and ability to simulate observables that can be compared to satellite observations (e.g., simulating radiance, instead of, or in addition to the use of satellite retrievals). This emerging science may lead to direct benefits for simulating and predicting phenomena and processes that are relevant to management and policy making in environment and water resources (with respect to floods, droughts, heat waves and fires).

Future plans

Some of the following issues are relevant for other GEWEX panels, GLASS may seek synergy in addressing them:

- **Surface water with an emphasis on lakes and reservoirs**: (links to ET and irrigation CC), km-scale theme, NASA Surface Water and Ocean Topography (SWOT) satellite launch
- Flood Inundation (extent, duration) activity: with GHP, GDAP?
- **Groundwater MIP?**: members of SoilWAt team, plus key panel members
- **"Soil-Cloud Cascades"**: Yijian Zeng (GLASS), Yunyan Zhang (GDAP) and others. Links to LoCo, CLASP, GLAFO, km-scale & mesoscale organization of convection themes, GASS and GHP
- Vegetation (proposed by German Poveda)
  - Amazon Volatile Organic compounds (VOCs), cloud nuclei. Get person on panel from Amazon community?
  - **Model improvements** in framework of satellite operational context (observables: VOD, optical spectra, brightness temperature
- **Urban PLUMBER**: Gert-Jan Steeneveld (Lead M. Lipson): km-scale & mesoscale organization of convection themes
- **Permafrost/snow** processes activity: Snow-MIP?: Link with CLiC
- **Machine learning** versus **processes**? (Gab Abramowitz, Martin Best, Laura Condon) opinion piece in GEWEX Newsletter in first instance?

Recommendations to Panel

The rapporteurs are very appreciative of the efforts of the GLASS panel and in particular the leadership of their two female co-chairs.
We recommend more frequent cross-panel discussions with other panels in addressing some common issues. The speed dating events with other panels were appreciate by all panels and should serve as best practice for future.
We also feel that expertise related to passive and active microwave satellites may be enhanced in the GLASS panel (e.g., in advancing the use of SMOS, SMAP, ROSE-L, CIMR etc. data in LSMs).

Considerations for SSG

Future SSG meetings should be collocated with panel's meetings. The benefits of listening to and talking to project leads cannot be overestimated. If logistics permits, these events should be organized as pan-GEWEX events.

Additional Remarks

The Monterey Pan-GASS, Pan-GEWEX and GEWEX SSG meetings have been very beneficial to the participants in understanding the objectives of GEWEX and in soliciting community efforts in furthering the science goals of GEWEX. Lots of thanks and appreciations are due to the GEWEX SSG co-chairs and panel co-chairs and especially to the staff of IGPO.

Annex 4: Acronyms and Other Abbreviations

Click for a list of acronyms and abbreviations related to climate research.

3MI	Multi-viewing, Multi-channel, Multi-polarization Imaging instrument
ACAM	Atmospheric Composition and the Asian Monsoon
ACCP	Aerosols, Clouds, Convection and Precipitation
ACPC	Aerosols, Clouds, Precipitation and Climate
AGU	American Geophysical Union
ALMIP2	Land Surface Model Intercomparison Project (CMIP)
ALOS	Advanced Land Observing Satellite series (JAXA)
ALPACA	Alaskan Layered Pollution and Chemical Analysis
AMMA	Multidisciplinary Analysis of the African Monsoon
AMOC	Atlantic Meridional Overturning Circulation Task Team (CLIVAR)
AMS	American Meteorological Society
AMSR2	Advanced Microwave Scanning Radiometer 2 (JAXA)
ARM	Atmospheric Radiation Measurement (U.S. Department of Energy)
ARMBE	ARM Best Estimate
ARTMIP	Atmospheric River Tracking Method Intercomparison Project
AsiaPEX	Asian Precipitation Experiment
ATOMIC	Atlantic Tradewind Ocean–Atmosphere Mesoscale Interaction Campaign
AWI	Alfred Wegener Institute
BB	Building Blocks (WCRP)
BEAR	Baltic Earth Assessment Reports
BSRN	Baseline Surface Radiation Network
C3S	Copernicus Climate Change Service
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
CASCADE	Calibrated and Systematic Characterization, Attribution and Detection of Extremes project
CAUSES	Clouds Above the United States and Errors at the Surface
CC	Cross-Cut Project
CCI	Climate Change Initiative (ESA)
CCI SM	Climate Change Initiative-Soil Moisture (ESA)
CCMP	Cross-Calibrated Multi-Platform
CCRN	Changing Cold Regions Network
CCSM	Community Climate System Model
CDR	Climate Data Record
CDR	Carbon Dioxide Removal
CDS	Climate Data Store
CEH-GEAR	Centre for Ecology and Hydrology Gridded Estimates of Areal Rainfall
CEMS	Copernicus Emergency Management Service
CEOS	Committee on Earth Observation Satellites
CERES	Clouds and the Earth's Radiant Energy System
CESM	Community Earth System Model
CFMIP	Cloud Feedback Model Intercomparison Project
CGMS	Coordination Group for Meteorological Satellites

CIRS	Composite Infrared Spectrometer
CII	Climate Impact Indicators
CLASP	Coupling Land and Atmospheric Subgrid Parameterizations
CLASS	Canadian Land Surface Scheme
CliC	Climate and Cryosphere Project (WCRP Core Project)
CLIVAR	Climate and Ocean–Variability, Predictability, and Change (WCRP Core Project)
CMAP	CPC Merged Analysis of Precipitation (NOAA)
CMIP	Coupled Model Intercomparison Project (WCRP)
CMORPH	CPC MORPHing technique (NOAA)
CNES	Centre National d'Études Spatiales (National Center for Space Studies)
CNRM	Centre National de Recherches Météorologique (National Center for Meteorological Research)
COLA	Center for Ocean-Land-Atmosphere Studies
CONUS	Contiguous United States
CONVEX	Research Project on Observational Evidence and Process Understanding to Improve Predictions of Extreme Rainfall Change
COORDE	COnstraining ORographic Drag Effects
CORA	Coordination Office for WCRP's Regional Activities
CORDEX	Coordinated Regional Climate Downscaling Experiment (WCRP)
CPC	Climate Prediction Center (NOAA)
CPO	Climate Program Office (NOAA)
CPT	Climate Process Teams
CPPA	Climate Prediction Program for the Americas
CRCM	Canadian Regional Climate Model
CRHM	Cold Region Hydrological Model
CRM	Cloud-Resolving Models
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTEM	Canadian Terrestrial Ecosystem Model
DECK	Diagnostic, Evaluation and Characterization of Klima experiment
DCP	Diurnal Cycle of Precipitation (GASS project)
DIAL	Differential Absorption Lidar
DICE	Diurnal Land/Atmosphere Coupling Experiment
DOE	Department of Energy
DOIs	Digital Object Identifiers
DWD	Deutscher Wetterdienst (German Weather Service)
DYAMOND	DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains
E3SM	Energy Exascale Earth System Model
EarthCARE	Earth Cloud, Aerosol and Radiation Explorer
EBAF-4	Energy Balanced and Filled (EBAF) Top-of-Atmosphere (TOA) Edition-4.0
EC-RTD	Research and Innovation Framework Programme of the European Union
ECA&D	European Climate Assessment and Dataset
ECCC	Environment and Climate Change Canada
ECMWF	European Centre for Medium-range Weather Forecasts
ECR	Early Careers Researcher
ECVs	Essential Climate Variables
EDO	European Drought Observatory

EFAS	European Flood Awareness System
EEI	Earth's Energy Imbalance
EESM	Earth and Environmental Systems Modeling program (DOE)
EESSD	Earth and Environmental Systems Sciences Division (DOE)
EGU	European Geosciences Union
EGU2020	European Geosciences Union General Assembly, 2020
EMS	European Meteorological Society
EO	Earth Observations
EO4SD	Earth Observation for Sustainable Development (ESA)
EO-Water	Division of Earth Observation for the Water Cycle (Chinese Academy of Sciences)
EPS-SG	EUMETSAT Polar System-Second Generation
ERA-Interim	ECMWF Re-Analysis (ERA)-Interim
ESA	European Space Agency
ESGF	Earth System Grid Federation
ESM	Earth System Model
ESMD	Earth System Model Development (DOE)
ESMO	Earth-System Modelling and Observation (WCRP Core Project)
ET	Evapotranspiration
ET CC	Determining Evapotranspiration Cross Cut
ETCCDI	Expert Team on Climate Change Detection and Indices
ETH	Swiss Federal Institute of Technology in Zürich
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EUREC^{4}A	Elucidating the Role of Clouds-Circulation Coupling in Climate field campaign
EV	Earth Venture
EVI	Earth Venture Instruments
EVM	Earth Venture Missions
EVS	Earth Venture Sub-orbital
EXAEDRE	Exploiting new Atmospheric Electricity Data for Research and the Environment
EXP1	Long-term Retrospective Experiment
FAIR	Findability, Accessibility, Interoperability, and Reusability
FCDR	Fundamental Climate Data Record
FDR	Fundamental Data Record
FE	Future Earth
FIDUCEO	Fidelity and Uncertainty in Climate data records from Earth Observations
FIREX-AQ	Fire Influence on Regional to Global Environments and Air Quality
FLEX	FLuorescence EXplorer mission
FMI	Finnish Meteorological Institute
FOCI	Frontiers of Climate Information (WCRP)
FORUM	Far-Infrared Outgoing Radiation Understanding and Monitoring mission
FPS	Flagship Pilot Study (HyMeX) (CORDEX)
FRM4SM	Fiducial Reference Measurements for Soil Moisture program
FROGS	Frequent Rainfall Observations on GridS database
GABLS	GEWEX Atmospheric Boundary Layer Study
GAIA-CLIM	Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring
GAP	GEWEX Aerosol Precipitation project
GAPP	GEWEX America Prediction Project
GATE	Global Atmospheric Research Program's Atlantic Tropical Experiment

GAW	Global Atmosphere Watch (WMO)
GC	Grand Challenge (WCRP)
GCIP	GEWEX Continental-Scale International Project
GCM	General Circulation Model
GCM	Global Climate Model
GCOM	Global Change Observation Mission (JAXA)
GCOM-C	Global Change Observation Mission-Climate (JAXA)
GCOM-W	Global Change Observation Mission-Water (JAXA)
GCOS	Global Climate Observing System
GDAP	GEWEX Data and Assessment Panel
GDC	Global Data Center
GDIS	Global Drought Information System
GDO	Global Drought Observatory
GEO	Group of Earth Observation
GERICS	Climate Service Center Germany
GEWEX	Global Energy and Water Exchanges (WCRP Core Project)
GFCS	Global Framework for Climate Services
GPP	Gross Primary Productivity
GHP	GEWEX Hydroclimatology Panel
GHRSST	Global High-Resolution Sea Surface Temperature
GLACE	The Global Land–Atmosphere Coupling Experiment
GLAFO	GEWEX Land/Atmosphere Feedback Observatory
GLASS	Global Land/Atmosphere System Study
GloFAS	Global Flood Awareness System
GMMIP	Global Monsoons Model Intercomparison Project
GNSS	Global Navigation Satellite Systems
GOES-16	Geostationary Operational Environmental Satellite-16
GOSAT-GW	Global Observation SATellite for Greenhouse gases and the Water cycle
GPCC	Global Precipitation Climatology Centre
GPCP	Global Precipitation Climatology Project
GPM	Global Precipitation Mission
GRACE	Gravity Recovery and Climate Experiment
GRDC	Global Runoff Data Center
GSDR	Global Sub-Daily Rainfall Dataset
GSFC	Goddard Space Flight Center (NASA)
GSICS	Global Space-based Inter-Calibration System
GSMaP	Global Satellite Mapping of Precipitation (JMA)
GSOP	Global Synthesis and Observations Panel (CLIVAR)
GSQs	GEWEX Science Questions
GSW	GEWEX Soils and Water
GSWP3	Global Soil Wetness Project 3
GSWP3-EXP1	Global Soil Wetness Project 3 long-term retrospective Experiment 1
GSWP3-EXP2	Global Soil Wetness Project 3 long-term future climate Experiment 2
G-VAP	GEWEX Water Vapor Assessment
GWF	Global Water Futures
GWIS	Global Water Information System (WMO)
HCP	Hydrological Coordination Panel (WMO)
HEPEX	Hydrologic Ensemble Prediction Experiment

HESS	Hydrology and Earth System Sciences
HIRS	High Resolution Infra-Red Radiation Sounder
HOAPS	Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data
HYDROLARE	International Data Centre on Hydrology of Lakes and Reservoirs
HydroSOS	Global Hydrological Status and Outlook System (WMO)
Hydro-TEP	Hydrology Thematic Exploitation Platform (ESA)
HyMeX	Hydrological cycle in the Mediterranean Experiment
HyVic	Hydrology of Lake Victoria Basin
IASOA	International Arctic Systems for Observing the Atmosphere
ICDR	Monthly Interim Climate Data Record (GPCP)
ICI	Ice Cloud Imaging instrument
ICPAC	Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre
ICSU	International Council for Science
ICWRGC	International Centre for Water Resources and Global Change
IDF	Intensity-Duration-Frequency
IGAC	International Global Atmospheric Chemistry
IGAD	Intergovernmental Authority on Development
IGBP	International Geosphere Biosphere Programme
IGPO	International GEWEX Project Office
IGWCO	Integrated Global Water Cycle Observations
IHP	Intergovernmental Hydrological Programme
IITM	Indian Institute of Tropical Meteorology
ILAMB	International Land Model Benchmarking
iLEAPS	integrated Land Ecosystem-Atmosphere Processes Study
INARCH	International Network for Alpine Catchment Hydrology
INCOMPASS	Interaction of Monsoon Precipitation and Convective Organization, Atmosphere, Surface and Sea field campaign
IndOOS-2	Indian Ocean Observing System 2
INTENSE	INTElligent use of climate models for adaptatioN to non-Stationary hydrological Extremes
IOC	Intergovernmental Oceanographic Commission (of UNESCO)
IOCCG	International Ocean Color Coordination Group
IOC-GOOS	Intergovernmental Oceanographic Commission-Global Ocean Observing System
IOGEO	Inter-calibration of passive imager observations from time-series of geo stationary satellites
IOP	Intensive Observation Period
IORP	Indian Ocean Region Panel
IPCC	Intergovernmental Panel on Climate Change (WMO, UNEP)
IPSL	Institute Pierre Simon Laplace
IPWG	International Precipitation Working Group
IQuOD	International Quality Controlled Ocean Database
IR	Raman lidar and infrared
ISC	International Science Council
ISCCP	International Satellite Cloud Climatology Project
ISCCP-NG	Next Generation International Satellite Cloud Climatology Project
ISI-MIP	Intersectoral Impact Model Intercomparison Project (CMIP)
ISMN	International Soil Moisture Network

ISSI	International Space Science Institute
IUGG	International Union of Geodesy and Geophysics
IWM-7	Seventh WMO International Workshop on the Monsoons
IWRM	Integrated Water Resources Management
JAXA	Japan Aerospace Exploration Agency
JEDI	Justice, Equity, Diversity, and Inclusion
JMA	Japanese Meteorological Association
JSC	Joint Scientific Committee (WCRP)
KMI	Belgium Meteorological Institute
KNMI	Royal Netherlands Meteorological Institute
L1G	Level 1Geo-coded data
LAC	Land-Atmosphere Coupling
LAFE	Land-Atmosphere Feedback Experiment
LAI	Leaf Area Index
LASSO	Large-Eddy Simulation ARM Symbiotic Simulation and Observation
LE	Latent Heat
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
LES	Large Eddy Simulation
LHA	WCRP's Lighthouse Activity
LIAISE	Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment
LIS	Land Information System (NASA)
LLNL	Lawrence Livermore National Laboratory
LMDZ GCM	Laboratoire de Météorologie Dynamique Global Climate Model
LoCo	Local Land-Atmosphere Coupling
LoCo WG	Local Land-Atmosphere Coupling Working Group
LS3MIP	Land Surface, and Snow, Soil moisture Model Intercomparison Project
LS4P	Impact of Initialized Land Temperature and Snowpack on Sub-Seasonal to Seasonal Prediction
LSM	Land Surface Model
LST	Land Surface Temperature
LUCID	Land-Use and Climate, IDentification of robust impacts
LULCC	Land Use Cover Changes
LUMIP	Land Use Model Intercomparison Project (CMIP)
MAC v1	Max Planck Aerosol Climatology version 1
MAHASRI	Monsoon Asian Hydro-Atmosphere Scientific Research and Prediction
MAPP	Modeling, Analysis, Predictions and Projections Program Mission
MCS	Mesoscale Convection Systems
MDF	Model Data Fusion
MEaSURES	Making Earth System Data Records for Use in Research Environments
Med-CORDEX	Mediterranean Coordinated Regional Downscaling Experiment
MERRA	Modern-Era Retrospective Analysis for Research and Applications
MESH	Modélisation Environmentale Communautaire (MEC)–Surface and Hydrology
MetOP-SG	Meteorological Operational Satellite-Second Generation
MIP	Model Intercomparison Project

MOSAiC	Multidisciplinary drifting Observatory for the Study of Arctic Climate
MOUNTerrain	GEWEX Mountainous Terrain Precipitation Project
MP	Monsoon Panel (GEWEX/CLIVAR Monsoons Panel)
MSD	MultiSector Dynamics (DOE)
MTG	Meteosat Third Generation
NARCCAP	North American Regional Climate Change Assessment Program
NASA	National Aeronautics and Space Administration
NEESPI	Northern Eurasia Earth Science Partnership Initiative
NEWS	NASA Energy and Water Cycle Studies
NCA	National Climate Assessment
NCAR	National Centers for Atmospheric Research
NCAR/RAL	Research Applications Laboratory of the National Center for Atmospheric Research
NCEI	National Center for Environmental Information
NCEP	National Center for Environmental Prediction
NDVI	Normalized Difference Vegetation Index
nnHIRS	neural network High Resolution Infra-Red Radiation Sounder
NOAA	National Oceanic and Atmospheric Administration (USA)
NRC	National Research Council
NSF	National Science Foundation
NWP	Numerical Weather Prediction
OAFlux	Objectively Analyzed Air-sea Fluxes
Obs4MIPS	Observations for Model Intercomparisons
OOPC	Ocean Observations Panel for Physics and Climate
ORA-IP	Ocean Reanalysis Intercomparison project
ORCHIDEE	Organizing Carbon and Hydrology In Dynamic Ecosystems
ORNL	Oak Ridge National Laboratory
OSC2023	WCRP Open Science Conference in 2023
OzEWEX	Australian Energy and Water Exchanges
PALS	Protocol for the Analysis of Land Surface models
PannEx	Pannonian Basin Experiment
PBL	Planetary Boundary Layer
PCMDI	Program for Climate Model Diagnosis and Intercomparison
PERLE	Pelagic Ecosystem Response to dense water formation in the Levant Experiment
PI	Principal Investigator
PILDAS	Project for the Intercomparison of Land Data Assimilation Schemes
PLUMBER	PALS Land Surface Model Benchmarking Evaluation Project
PMM	Precipitation Measurement Mission
PNNL	Pacific Northwest National Laboratory
POC	Point of Contact
POD	Process-Oriented Diagnostic
PPGC	Precipitation Prediction Grand Challenge (NOAA)
PROES	Process Evaluation Study
PTF	Pedotransfer Functions
Qa	Atmospheric humidity
QA4EO	Quality Assurance for Earth Observations

QA4SM	Quality Assurance for Soil Moisture
RADI	Institute of Remote Sensing and Digital Earth (Chinese Academy of Sciences)
RAOBS	Paposo Lower Site Radiosondes
RCM	Regional Climate Model
REGEN	Rainfall Estimates on Gridded Network database
RF	Research Focus (CLIVAR)
RF TBI	Research Focus on Tropical Basin Interaction (CLIVAR)
RGMA	Regional Global Modeling Analysis (DOE)
RHPs	Regional Hydroclimate Projects
RifS	Regional Information for Society (WCRP Core Project)
S-RIP	SPARC Reanalysis Intercomparison Project
S2S	Subseasonal to seasonal
S2S	Subseasonal to Seasonal Prediction Project
SACRA	Global data sets of satellite-derived crop calendars for agricultural simulations
SAFRAN-IP	Système d'Analyse Fournissant des Renseignements Atmosphériques à la Neige for the Iberian Peninsula
SAIL	Surface Atmosphere Integrated Field Laboratory
SAP	Scientific Advisory Panel (WMO)
SAR	Synthetic Aperture Radar
SATIO-TCS	Stratospheric and Tropospheric Influences on Tropical Convective Systems
SATM	Science and Applications Traceability Matrix
SCI	Solar Climate Intervention
SCM	Single Column Model
SCO	Space Climate Observatory (CNES)
SCOPE-CM	Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring
SCOR	Scientific Committee on Oceanic Research
SGP	Southern Great Plains ARM site (USA)
SMAP	Soil Moisture Active Passive (NASA)
SMOS	Soil Moisture and Ocean Salinity (ESA)
SNAP	SPARC Network on Assessment of Predictability
SoilWat	GEWEX Soil and Water Initiative
SOP	Special Observation Period
SP	Super Parameterization
Space for IDA	Space in support of International Development Assistance
SPARC	Stratospheric Processes and their Role in Climate (WCRP Core Project)
SRB	Surface Radiation Budget project
SREX	*Special Report for Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (IPCC)
SSC	Scientific Steering Committee
SSCZP	Soil Systems and Critical Zone Processes
SSG	Scientific Steering Group (GEWEX)
SSiRC	Stratospheric Sulfur and its Role in Climate
SSMIS	Special Sensor Microwave Imager/Sounder
SST	Sea Surface Temperature
STC	Science and Technology Corporation
SUBT	Subsurface Temperature

SWOT	Surface Water and Ocean Topography satellite
TANSO-3	Total Anthropogenic and Natural emissions mapping SpectrOmeter-3
TBI	Tropical Basin Interaction (CLIVAR)
TEP	Thematic Exploitation Platform
TEAMx	mulTi-scale transport and Exchange processes in the Atmosphere over Mountains – programme and eXperiment
THORPEX	The Observing system Research and Predictability Experiment
TIRA	Task Team for Intercomparison of Reanalyses (WCRP)
TOA	Top Of Atmosphere
TOOCAN	Tracking Of Organized Convection through a three dimensional segmentatioN
TPE	Third Pole Environment
TPE-WS	Third Pole Environment–Water Sustainability
TRACER	Tracking Aerosol Convection Interactions Experiment
TTRA	Task Team on Regional Activities (WCRP)
TU Wien	Vienna University of Technology
UCAR	University Corporation for Atmospheric Research
UCI	University of California, Irvine
UKMO	UK Met Office
UKWIR	UK Water Industry Research
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNSW	University of New South Wales, Sydney, Australia
URC	International Radiation Commission
USDA	United States Department of Agriculture
USGCRP	U.S. Global Change Research Program
USRA	Universities Space Research Association
UT	Upper tropospheric
UTLS	Upper Troposphere Lower Stratosphere
UTTC	Tropospheric Clouds and Convection
UTCC PROES	GEWEX Upper Tropospheric Clouds and Convection Process Evaluation Study
VOD	Vegetation Optical Depth
WACCEM	Water Cycle and Climate Extremes Modeling
WACMOS-ET	Water Cycle Observation Multi-mission Strategy-EvapoTranspiration
WAVAS-II	Screened Water Vapour Assessment 2
WCRP	World Climate Research Programme (WMO, IOC and ICSU)
WDAC	WCRP Data Advisory Council
WECC	Water, Ecosystem, Cryosphere and Climate (CCRN)
WG	Working Group (CLIVAR/GEWEX Global Monsoon Panel)
WGCM	Working group on Coupled Modelling (WCRP)
WGIR	Working Group on Information for Regions (WCRP, to be approved)
WGNE	Working Group of Numerical Experimentation
WGRC	Working Group on Regional Climate (WCRP)
WGSIP-LRFM	Working Group on Seasonal to Interannual Prediction–Long-Range Forecast Monsoon

WMO	World Meteorological Organization
WMO SPICE	World Meteorological Organization's Solid Precipitation Intercomparison Experiment
WRMC	World Radiation Monitoring Center
WRMC-BSRN	World Radiation Monitoring Center-Baseline Surface Radiation Network
WRF	Weather Research and Forecasting
WWRP	World Weather Research Programme
YESS	Young Earth System Scientists Community
YHS	Young Hydrologic Society

The
World Climate Research Programme (WCRP)
facilitates analysis and prediction of Earth system change for use in a range of practical applications of direct relevance, benefit and value to society.