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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.

<i>Dr. Ir. P. van Oevelen</i>	<i>Director, GEWEX International Project Office</i>
<i>Dr. J. Polcher</i>	<i>Co-Chair, GEWEX SSG</i>
<i>Dr. G. Stephens</i>	<i>Co-Chair, GEWEX SSG</i>
<i>Dr. G. Balsamo</i>	<i>GEWEX SSG Member</i>
<i>Dr. M. Bosilovich</i>	<i>GEWEX SSG Member</i>
<i>Prof. Dr. P. Dirmeyer</i>	<i>GEWEX SSG Member</i>
<i>Dr. G. Hegerl</i>	<i>GEWEX SSG Member</i>
<i>Dr. C. Jakob</i>	<i>GEWEX SSG Member</i>
<i>Prof. Dr. G. Poveda</i>	<i>GEWEX SSG Member</i>
<i>Prof. Dr. B.J. Sohn</i>	<i>GEWEX SSG Member</i>
<i>Prof. Dr. Z. Su</i>	<i>GEWEX SSG Member</i>
<i>Dr. S. Bony</i>	<i>Co-Chair, GASS Panel</i>
<i>Dr. D. Klocke</i>	<i>Co-Chair, GASS Panel</i>
<i>Prof. Dr. X. Zeng</i>	<i>Co-Chair, GASS Panel</i>
<i>Dr. R. Roca</i>	<i>Co-Chair, GDAP Panel</i>
<i>Prof. Dr. T. L'Ecuyer</i>	<i>Co-Chair, GDAP Panel</i>
<i>Prof. A. Nazemi</i>	<i>Co-Chair, GHP Panel</i>
<i>Prof. F. Dominguez</i>	<i>Co-Chair, GHP Panel</i>
<i>Dr. K. Findell</i>	<i>Co-Chair, GLASS Panel</i>
<i>Prof. A. Verhoef</i>	<i>Co-Chair, GLASS Panel</i>

The **Global Energy and Water Exchanges (GEWEX)** project is a core project of 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.

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This report is a representation of the discussions and meeting outcomes of the GEWEX Scientific Steering Group Meeting and hence should not be considered a consensus report.

Executive Summary

This report documents the proceedings of the 33rd 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. Originally hosted by the Seoul National University in Seoul, South Korea, the meeting had to be moved to an online setting due to COVID-19. The attendees reviewed the progress of GEWEX and its four Panels for the year 2020 and discussed the program's relevance today and tomorrow.

All four GEWEX Panels reported many activities in 2020 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.

As of June 17, 2020, the support required to meet the obligations and responsibilities of the International GEWEX Project Office (IGPO) has been taken over by George Mason University under the Center for Ocean-Land-Atmosphere Studies (COLA).

In anticipation of Phase IV (2023–2032) of GEWEX, a “Science and Applications Traceability Matrix” (SATM) is being assembled with input from all SSG and Panel members. The GEWEX SATM will provide traceability from WCRP strategies to core science, defined metrics, applications and programs. It will serve as the backbone of, and provide direction to, the revision of the GEWEX strategic plan and science questions for the coming years.

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1. Introduction and Overview

This report summarizes the main developments in GEWEX during the year 2020 and includes the major items and recommendations from the 33rd Session of the GEWEX Scientific Steering Group (SSG-33).

The GEWEX SSG-33 was originally planned to take place at the Seoul National University in Seoul, South Korea. Unfortunately, due to the COVID-19 pandemic, the event was rescheduled as an online meeting from 3–6 May 2021. Besides GEWEX Scientific Steering Group (SSG) members and GEWEX Panel Co-Chairs, representatives from the National Centre for Space Studies (CNES), Copernicus Climate Change Service, the U.S. Department of Energy (DOE), 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), U.S. Global Change Research Program (USGCRP), United Nations Educational, Scientific and Cultural Organization (UNESCO), World Climate Research Programme (WCRP), WCRP's core programs and working groups and other collaborating partners of GEWEX participated in this meeting. The full list of participants can be found in Annex 1 and the agenda of this meeting 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 both WCRP and WMO focused on the transitions they are going through and gave insight into their new Strategic Plans. In this paragraph presentations from GEWEX's sister core projects showed their recent achievements and plans for the near future and include introductions by two new WCRP homes that are in the process of being formed, namely: i) WCRP Regional Information for Society (RifS) and ii) Earth System Modelling and Observational Capabilities (ESMOC). Information on the joint activities with GEWEX's sister project Climate and Ocean – Variability, Predictability and Change (CLIVAR) in the CLIVAR/GEWEX Monsoon Panel and developments with respect to WCRP's Grand Challenges (GC) on “Clouds, Circulation and Climate Sensitivity”, “Weather and Climate Extremes” and “Water for the Food Baskets of the World” are covered in §1.4. In this section more information on the progress of the five recently formed WCRP Lighthouse Activities (LHAs) and the five Regional Focal Point groups (RFPs) can be found.

Interactions with other GEWEX sponsors and partners are described in §1.3. Their presentations focused on recent achievements and plans for the future and showed 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 Scientific Steering Group (SSG) shapes and monitors the course of GEWEX and briefs WCRP’s Joint Steering Committee (JSC). The SSG consists of 10 members, two Co-Chairs 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 different 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), the CLIVAR/GEWEX Monsoon Panel, the WCRP Grand Challenge (GC) on “Clouds, Circulation and Climate Sensitivity”, “Weather and Climate Extremes” and the GC on “Water for the Food Baskets of the World”. All WCRP GCs are in their final year and will officially sunset at the upcoming WCRP Open Science Conference in 2022. GEWEX representatives also participate in the five newly formed WCRP Lighthouse Activities (LHA) 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) is being assembled with input from all SSG and Panel members. The GEWEX SATM will provide traceability from WCRP strategies to core science, defined metrics, applications and programs. It will serve as the backbone of, and provide direction to, the revision of the GEWEX strategic plan and science questions for the coming years.

The International GEWEX Project Office (IGPO) facilitates and coordinates GEWEX research across the GEWEX studies, activities and products. IGPO oversees the implementation of the recommendations given by the GEWEX Scientific Steering Group (SSG) and plays 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 provides an interface between GEWEX and other WCRP activities, as well as other global environmental science and space science programs. Until June 16, 2020, Universities Space Research Association (USRA) and Science and Technology Corporation (STC) provided the support required to meet the obligations and responsibilities of IGPO and its Director directly or indirectly through access to the necessary facilities and staffing. This support was taken over by George Mason University under the Center for Ocean-Land-Atmosphere Studies (COLA) as of June 17, 2020. During the 2020 reporting period, IGPO, in addition to its regular daily duties, meetings and activities, focused on: i) finding collaboration partners and expanding its network in Central Asia and Africa; ii) assisting with the promising start of reintroducing a Regional Hydroclimate Project (RHP) in the United States; iii) supporting the initiating RHP ANDEX with drafting its white book and moving towards becoming a full RHP; iv) supporting and advancing the GEWEX Land/Atmosphere Feedback Observatory (GLAFO) Project and v) assisting in the organization of the Pan-GASS Meeting, which has been rescheduled to July 2022 as travel restrictions will still be in place due to COVID-19.

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

activities are designed to facilitate and support the international community that carries out and uses observations, process studies and numerical model experiments. The goal is to advance the understanding of atmospheric processes and to develop and improve the representation of the atmosphere in weather and climate models.

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

1. Convective precipitation—including diurnal cycle (timing and intensity); the organization of convective systems; precipitation intensity and distribution; and the relationship with column-integrated water vapor, SST and vertical velocity
2. Cloud microphysics, including errors linked to mixed-phase, supercooled liquid cloud and warm rain
3. Precipitation over orography—spatial distribution and intensity errors

The COncstraining ORographic Drag Effects (COORDE) project has been particularly successful in identifying the importance of drag and has advanced some of the parameterization. Phase 2 is completed and concluded with a published paper. Discussion to continue the collaboration in this group is ongoing, with a possible COORDE-like experiment over the Rocky Mountains. Information about current and future model development on orographic drag from the various collaborators is being gathered.

The Demistify project, a Large Eddy Simulation (LES) and Numerical Weather Prediction (NWP) fog modelling intercomparison, has a large modeling component in Phase I. The project is progressing again after a period of lying dormant in 2020. The draft paper is ready for submission and shows that significant variation exists between models. 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.

Phase I of the Impact of Initialized Land Temperature and Snowpack on Sub-Seasonal to Seasonal Prediction (LS4P) project is completed (Fig. 1). 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 for publication is submitted and under review. Additionally, *Climate Dynamics* published a special issue on LS4P. LS4P Phase II will focus on the Land Surface Temperature effect in the Rocky Mountains.

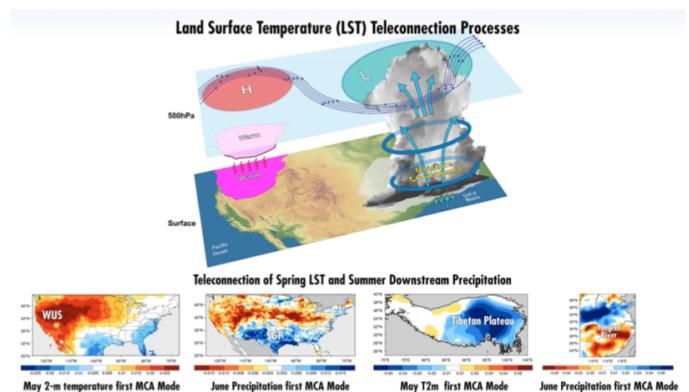


Fig. 1. LS4P organization and design

The diurnal and sub-diurnal precipitation project, which aims to improve the simulation of diurnal and sub-diurnal precipitation over different climate regimes (the Great Plains in the U.S. and the Amazon region) completed Phase I. The paper on this project will be submitted shortly

and includes results from multi-year SCM runs over the two climate regimes. Phase I will be followed up with LES, Cloud-Resolving Modeling (CRM) and General Circulation Modeling (GCM) studies.

The affiliated GEWEX Upper Tropospheric Clouds and Convection Process Evaluation Study (UTCC PROES) released two data sets from 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. The second key result in 2020 is the construction of a 3-D structure of upper tropospheric (UT) cloud systems from machine learning Composite Infrared Spectrometer (CIRS) data and ERA Interim, which were trained with 4 Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO)-CloudSat data (radiative heating rates from FLXHR). The other two affiliated projects, the GEWEX Atmospheric Boundary Layer Study (GABLS-4) and the GEWEX Aerosol Precipitation initiative (GAP), are advancing at a steady pace.

The year 2020 is also marked by the organization of the Pan-GASS Meeting, originally scheduled to take place in 2021 and now rescheduled to July 2022 due to the COVID-19 situation. The Pan-GASS meeting will host two competitions for Early Careers Researchers (ECRs) to stimulate 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 U.S. Department of Energy. The third ECR competition is organized by WCRP and the GEWEX GASS Panel and will cover poster and oral presentations competencies.

GASS Panel members contributed to the development of a position paper of the WCRP modeling groups to the WCRP chairs, and a position paper led by WGNE concerning the reorganization of WCRP modeling activities. Furthermore, a survey was set up with WGNE aimed at Modeling Centers concerning shortcomings in process representations in climate and NWP models. This led to further discussion about complementary topics and common interests between WGNE and the GASS co-chairs. Other interactions and reporting activities concerned the World Weather Research Program (WWRP), the CLIVAR/GEWEX Monsoon Panel on potential collaborations and WCRP's core project "Stratospheric Processes And their Role in Climate" (SPARC) on both UTCC PROES and COORDE activities.

For the coming year, GASS aims at sharpening its scientific goals and further collaborating with the other GEWEX Panels and partners in the WCRP community. GASS wants to focus more on understanding of atmospheric processes and on the role of scale interactions in the atmosphere. It will facilitate and ensure complementarity with WGNE, and address fundamental challenges in atmospheric science, including those pointed out by the (sunsetting) WCRP GCs and those arising with the new WCRP Lighthouse activities (LHA). In this context, GASS continues to explore new ideas for potential projects, such as process studies motivated by GC projects EUREC4A (Elucidating the role of clouds-circulation coupling in climate) and shallow convective processes, surface fluxes over ocean and convective organization. Although the GASS Panel expanded in 2020 to include an ECR from South America, there are still openings for new members from Asia and Africa.

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?” Following through on the recommendations from the discussion on the identity of GDAP in 2018, GDAP is emerging as planned after rescoping and consolidating activities.

GDAP is climate-oriented, consistency-driven and focused global and worldwide, where observations are centric to its activities. The GDAP web pages have been updated to reflect this transition. The 2019 Panel meeting hosted by the University of Arizona in Tucson, AZ in January 2020 also followed suit with the implementation of a new meeting format that included more invited speakers. Due to the COVID-19 pandemic, the 2020 GDAP meeting, originally planned to take place in Paris, France, in October 2020, had to be moved to an online setting and shortened to basic reporting of each panel activity and discussion on the International Satellite Cloud Climatology Project – Next Generation (ISCCP-NG). The GDAP Panel welcomed two new members while two long-standing outgoing Panel members will remain affiliated with GDAP as lead and co-lead contributors.

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).

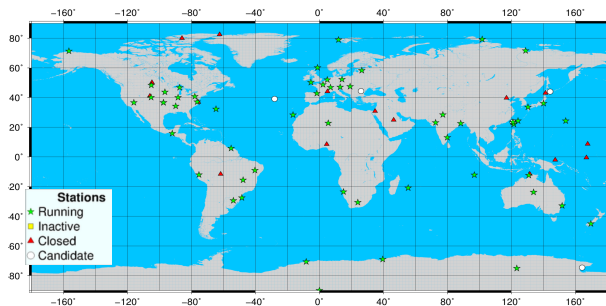


Fig. 2. Running, Inactive, planned and closed BSRN Stations, May 2021

The objective of the WRMC-BSRN network is to provide observations of the best possible quality for short- and long-wave surface radiation fluxes with a high sampling rate (Fig. 2). In this, WRMC-BSRN is supported by the Global Climate Observing System (GCOS) and GDAP jointly. GDAP helps maintain engagement and connection to the satellite issue on the surface radiation budget. In this reporting period, WRMC-BSRN and the Ocean

Observations Panel for Physics and Climate (OOPC) organized a splinter meeting on land/ocean radiation community interaction at the annual European Geosciences Union General Assembly (EGU2020) in April 2020. The goal of this meeting was to establish a dialog across both communities that measure surface solar and longwave radiation over land and sea. At the WRMC-BSRN 2020 virtual meeting in October 2020, six stations presented their plans to join the WRMC-BSRN activities. This reporting year is also marked by the appointment of a new deputy director and the setting up of a pilot project within the Data Quality Working Group for the production of centralized BSRN quality control statistics.

In 2020, GPCC increased its database with respect to the number of quality-controlled stations to 122,964 stations inter alia by integrating large data sets from Iran, Canada, Brazil and unique data contributions from Central Africa. Several V.2020 data have been released from the GPCC product portfolio e.g., Precipitation Climatology, Monitoring Product and the Full Data Monthly for 1891–2017.

ISMN boasts 71 networks with over 2800 stations and is integrated in the Quality Assurance for Earth Observations (QA4EO) platform to facilitate a transparent and traceable Soil Moisture Assessment. The transfer of ISMN operations from TU Wien, Austria, to the German Ministry of Infrastructure and Transport, initially discussed in 2019, is now underway. Operation of the ISMN at TU Wien will continue by ESA Quality Assurance for Earth Observations (QA4EO)

program until at least May 2022. The funding of Research and Development activities of ISMN are covered by European Space Agency (ESA) Fiducial Reference Measurements for Soil Moisture program (FRM4SM) until May 2023.

GDAP has three ongoing assessments. The GEWEX Water Vapor Assessment (G-VAP) phase II report originally expected in the fall of 2020 has been delayed by a year due to COVID-19. It will relate how water vapor products from satellite in situ and re-analysis do compare on some climatological time scale. The Precipitation Assessment will be released in 2021 after three years of dedicated work by 19 co-authors. All data and the database Frequent Rainfall Observations on GridS (FROGS) are released and is open to the public. This allows people to contribute to this kind of comparison by doing their own analysis beyond the report. Resulting from a Workshop organized by members of the working group and WCRP GC on Weather and Climate Extremes and GDAP a special issue in an environmental research letter with 20 articles was published in 2020. The third assessment relates to the Earth Energy Imbalance (EEI) and is a new activity in GDAP. This assessment will cover the capability to document the EEI and its variability including trends at various scales using various approaches, including in situ, satellite and reanalysis.

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. However, extension in time of the individual products is likely to happen. At this time, a reference paper is being written. The GEWEX IP workshop originally planned to take place in Toledo, Spain, in 2019 has been postponed twice on account of COVID-19. The aim of this workshop will now be redefined to develop the foci of a cross-panel GDAP-GLASS activity centering on land-atmosphere heat and moisture exchanges. This new project will fill a long-desired need to better engage local field sites like those from the Atmospheric Radiation Measurement (ARM) facilities, BSRN, etc. in GDAP regional and global assessments. In addition, it will 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 to support cloud science and takes advantage of the next generation geostationary platforms. In this reporting period, the initial version of Level 1 Geo-coded (L1G) radiance products are completed. Initial examination of L1G data revealed a wealth of unique time-varying data at small spatial scales. Additionally, the Geostationary Operational Environmental Satellite-16 (GOES-16) and -17 showed radiance discontinuities that stress the importance of a coordinated intercalibration effort through the Global Space-based Inter-Calibration System (GSICS). The next step will be to create a 1-year data set after which GDAP can organize an assessment.

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), Cross-cut Projects (CCs), Global Data Centers (GDCs) and GHP Networks.

RHPs are generally large, regionally-focused multidisciplinary projects that aim to improve the understanding and prediction of that region’s weather, climate and hydrology. There are three active, four prospective and three envisioned RHPs at this time. The Hydrological cycle in the Mediterranean Experiment (HyMeX), one of the active RHPs, conducts monitoring and modeling of the Mediterranean coupled system (atmosphere-land-ocean), its variability from event scale to the seasonal and interannual scales and characteristics within the context of global change in the 2010–2020 period. More than 400 scientists from 20 countries participated in this project. An overview paper will be prepared to highlight its most important achievements and contributions. 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 is scheduled for the summer of 2021 with a focus on semi-arid surface processes and human influence on the water cycle.

The second active RHP, Baltic Earth, studies Earth system science in the Baltic Sea region. Two of its main activities are the Baltic Earth Assessment Reports (BEAR) and EN Clime. BEAR are a series of extensive assessment reports that are currently in preparation. EN Clime is a joint Helsinki Commission-Baltic Earth expert network for climate change in the Baltic Sea region. Its primary goal is the production of a concise "Baltic Sea climate change fact sheet", which is almost finished. This fact sheets will contain a consensus view by the region’s climate experts on parameters, both biotic and abiotic, identified as of relevance to the policy process. Both BEAR and En Clime are very large collaborative and interdisciplinary undertakings. In 2020, *Frontiers* published a special issue dedicated to “The Baltic Sea Region in Transition” and included 20 articles. Baltic Earth also contributed to the Oxford Research Encyclopedia on “Climate Science”.

The research co-created in collaboration with Indigenous communities of the third active RHP, Global Water Futures (GWF), is focused on (Fig. 3):

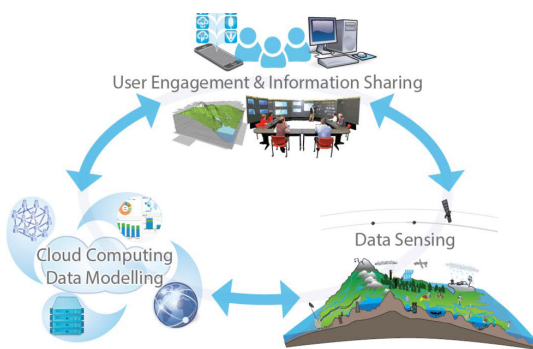


Fig. 3. Global Water Futures (GWF) Science Pillars

- 1) improving disaster warning by developing scientific knowledge, monitoring and modeling technologies and national forecasting capacity to predict the risk and severity of extreme events;
- 2) predicting water futures by using Big Data to make informed decisions and developing better models to assess change in human/natural land and water systems; and
- 3) inform adaptation to change and risk management to reduce the risk of water threats, design adaptive strategies and enhance economic opportunities.

A follow up to the former Monsoon Asian Hydro-Atmosphere Scientific Research and Prediction Initiative (MAHASRI) RHP is the Asian Precipitation EXperiment (AsiaPEX). This group advanced with publications, documenting observations and estimation, as well as process studies and analyses of predictability. Also, a new *Bulletin of the American Meteorological Society* (BAMS) article is underway. AsiaPEX aims to become a GEWEX RHP in 2021. Once the white book is approved, they will engage with the CLIVAR/GEWEX Monsoon Panel.

The 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 2020, a series of articles published in the *Frontiers* special on the Andes forms the backbone of its white book.

The U.S.-RHP “Water on the Edge in the Anthropocene” is another initiating RHP on the verge of applying for the GEWEX RHP status. This RHP is a cohesive multi-institutional effort to understand and address a changing hydroclimate in the United States (Fig. 4). At the core of this project is an observational network and a 40-year simulation in the Contiguous United States (CONUS) region.

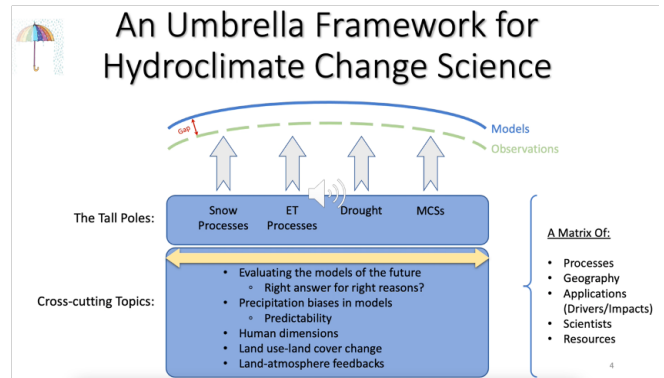


Fig. 4. Initiating U.S. RHP “Water on the Edge in the Anthropocene” science

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 achieved many results in 2020 e.g., completing two overseas centers, publishing four data sets for many meteorological and environmental variables and setting up about 17 Planetary Boundary Layer (PBL) towers for land-atmosphere interaction measurements. The biggest challenge for GHP and the TPE-WS project members will be to carefully define how TPE-WS will fit into GHP.

In 2020, many activities were initiated or continued from previous periods towards forming new research communities, which could lead to the three envisioned RHP’s which cover the Central Asian high mountains, East African mountain range and New Zealand.

Cross-cutting 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. The International Network for Alpine Catchment Hydrology (INARCH) CC focused on understanding hydrological processes in alpine cold regions. Among many other highlights and key results, INARCH led a special issue of the journal *Earth System Sciences Data* "Hydrometeorological data from mountain and alpine research catchments" and includes 23 data papers so far with more continuing to be submitted. The first phase of INARCH is now completed. Its leaders are currently reflecting on how to move forward and what the second phase should entail. There exist clear links between INARCH and the RHPs: TPE-WS, U.S.-RHP and ANDEX.

The INTElligent use of climate models for adaptationN to non-Stationary hydrological Extremes (INTENSE) CC collected and analyzed sub-daily precipitation data and model outputs. The data has been added to the GPCC global repository. This activity is officially finished. There is some thought concerning a follow-up CC related to floods or floods and droughts.

The mulTi-scale transport and Exchange processes in the Atmosphere over Mountains – programme and eXperiment (TEAMx) CC aims to improve the understanding of atmospheric processes specific to mountainous regions, which heavily affect the exchange of momentum, heat and mass between the Earth’s surface and the atmosphere. The Innsbruck University press published TEAMx’ white paper in June 2020. The plan for a TEAMx Observational Campaign has largely been prepared. In 2021, a second TEAMx workshop will focus on further refining the details with input from the TEAMx Working Groups. At this time, TEAMx is mainly

focused on the European Alps. It hopes to expand this area and collaboration with INARCH seems a good way forward.

The prospective CC Determining Evapotranspiration (ET) is an activity focusing on advancing the understanding and determination of evapotranspiration. Project members are working on a proposal to formally join GHP. This CC will provide many opportunities for inter-Panel activities within GEWEX.

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](#)). The activities of GPCC in this reporting period have already been described in the section on GDAP (pg. 5).

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. The database of quality controlled “historical” mean daily and monthly discharge data grows steadily and currently comprises river discharge data of well over 10,000 stations from 159 countries. With the implemented of an online Data Portal in June 2020, the number of data requests have increased approximately eightfold in the second half of 2020 compared to the whole of 2019. Also, 2020 marked the completion of the second edition of “Major River Basins of the World” and the third edition of “WMO Basins and Sub-Basins”. Both editions are based on the [HydroSHEDS](#) database and are available for download from the [GRDC](#) website.

HYDROLARE currently holds water level data for 1047 lakes and reservoirs in the world in 46 countries. One of the notable activities in 2020 was the continued development of a HYDROLARE IT infrastructure to improve customer service. GHP aims for more international input in HYDROLARE in order to improve interaction and communication with its members and to make this a more global effort.

GHP Networks are required to maintain collaboration and capacity building activities relevant to GEWEX science. Due to funding challenges, the former initiating RHP Pannonian Basin Experiment (PannEx), which focuses on the water and energy cycles in the Pannonian basin, transitioned to become a GHP Network for the time being. The second GHP Network is the Australian Energy and Water Exchange (OzEWEX) initiative. The main purpose of OzEWEX is to provide a coordinated environment to encourage collaboration among researchers and research users that brings benefits for the individuals involved, while at the same time working towards the OzEWEX objective set out in the Science Plan 2014–2019.

During the virtual 2020 GHP Meeting in November, there were a few Panel-membership changes, including both a new incoming co-chair and GLASS liaison. Panel members serve as liaisons with both the RHPs and the broader WCRP activities such as the Regional Information for Society (RIfS) home and the Lighthouse Activity “My Climate Risk”.

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 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.

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 the enhanced adoption of the LoCo paradigm at operational centers, use of LoCo metrics and diagnostics for integrative analysis and field campaigns (past and future) include LoCo-driven activities.
- *Plumber2*, the Protocol for the Analysis of Land Surface Models (PALS) Land Surface Model Benchmarking Evaluation Project, phase 2, which is a model comparison experiment that uses out-of-sample empirical models as benchmarks.
- *GEWEX Soil and Water Initiative* (SoilWat), which brings together two research communities to understand and improve representation of soil physics and groundwater transport in Earth system models at local to global scales. An important accomplishment of this project is the provision of guidelines based on the obtained results for the selection of PedoTransfer Functions (PTFs) in large scale models. Harmonization of PTFs used in model intercomparison studies is strongly advised to avoid artifacts originating from the choice of PTF rather than from different model structures. A new initiative of the SoilWat working group still in the early stages is the Evaluation Metrics for Soil Processes.
- *GEWEX/GLASS Land-Atmosphere Feedback Observatories* (GLAFO). Based on the success of the Land-Atmosphere Feedback Experiment (LAFE; 2017), this project proposes a new sensor synergy and/or enhancements of current observatories and networks to observe the atmospheric leg of land-atmosphere feedbacks. It will make measurement of L-A feedback in heterogeneous terrain possible and will form the basis of new generation of international experiments and observatories (Fig. 5).

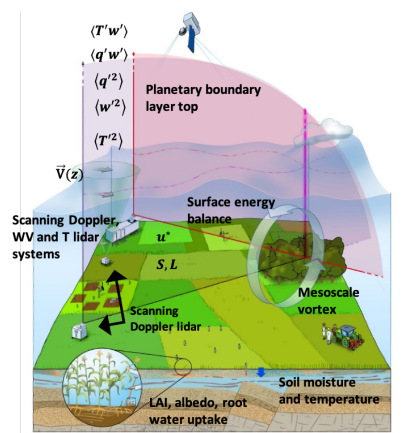


Fig. 5. GLAFO Design, from Wulfmeyer et al., *GEWEX Quarterly*, Vol. 30, Quarter 1, 2020

- *DICE/GABLS-4*: Diurnal land/atmosphere Coupling Experiment/GEWEX Atmospheric Boundary Layer Study is a joint GLASS-GASS experiment which studies 1-D interactions between land-surface and atmospheric boundary layer model experiments. This project is on hold at this time.

Projects in the Benchmarking Group are:

- *Plumber2*: Protocol for the Analysis of Land Surface Models (PALS) Land Surface Model Benchmarking Evaluation Project, phase 2, which is a model comparison experiment that uses out-of-sample empirical models as benchmarks.
- *PALS/modevaluation.org* is a web-based platform for evaluating and benchmarking computational models.

- *The International Land Model Benchmarking (ILAMB)* project developed a global benchmarking toolkit for climate model variables (seasonal to annual) and consolidated the location for data sets and diagnostics relevant to land and vegetation modeling communities. ILAMB is widely used by several modeling centers and intercomparison projects. The next steps are aimed at further development of ILAMB to enhance utility in model development, such as developing a prototype of diurnal cycle metrics, land-atmosphere coupling metrics, land use change metrics, etc.

The Model Intercomparison Projects (MIP) are:

- *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)* assessed 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.

During the virtual 2020 GLASS Meeting in November 2020, significant changes were made to the Panel membership, including both a new incoming co-chair and GDAP liaison. Going forward, the Panel plans to:

- update the formulation of GLASS rationale, strategies and links between projects, culminating in a long overdue stock-taking and perspective paper in *BAMS*, *Review of Geophysics*, and others;
- set up a dedicated GLASS webpage where tools, effort, impacts of GLASS efforts on (research on and solutions to) societally important topics such as extremes (heat waves, floods, droughts) and climate change are showcased;
- appoint a new Panel member and start a new activity (involving urban PLUMBER, etc.) dedicated to improving understanding and predictions of interactions between urban land surfaces and the atmosphere;
- focus on closing the interactive and iterative loop between the three GLASS strands (Process Modeling, Benchmarking and MIPs) via the use of physically meaningful diagnostic tools and metrics;
- closer collaborations with the other GEWEX Panels (e.g., GDAP) to create a coherent set of heat (latent and sensible) fluxes for land surface, ocean and land ice (observations, model outputs or a mix); and
- prepare clear, coherent and timely communications to the Global (Land) Modeling Community, e.g., via overview or review papers in *BAMS*, *Review of Geophysics*, and more.

1.2 GEWEX Links to WMO, WCRP and WCRP Core Projects

GEWEX’s parent organization, WCRP, falls under the umbrella of the World Meteorological Organization (WMO). The WMO vision states that by 2030, it sees a world where all nations, especially the most vulnerable, are more resilient to the socioeconomic consequences of extreme weather, climate, water and other environmental events; and underpin their sustainable development through the best possible services, whether over land, at sea or in the air (and in space). The WMO Strategic Plan sets out long-term goals for the 2030 horizon and strategic objectives, focused on addressing the most pressing developments and needs during the 2020–2023 planning cycle. Its overarching priorities for this period are to enhance preparedness for and reduce losses from hydrometeorological extremes, support climate-smart decisions to build or enhance adaptive capacity and resilience to climate risks and enhance socioeconomic value of weather, climate, hydrological and related environmental services.

The Research Board on Weather, Climate, Water and the Environment (Research Board) translates the strategic aims of WMO and the decisions of the Executive Council and Congress into overarching research priorities. The Research Board ensures the implementation and coordination of the research programs to achieve these priorities and to accelerate the science to service chain. The Research Board is advised by the Scientific Advisory Panel (SAP), whose role is to provide forward-looking strategic advice on emerging challenges and opportunities. The Science and Innovation Department of WMO provides leadership in research activities towards advancing scientific knowledge of the Earth system combined with the exploitation of cutting-edge technologies. Additionally, it provides leadership towards enhancing the science-for-service value chain by addressing the interests and needs of users and member states through improved predictive capabilities, strengthening regional and national innovation capabilities and in advancing policy-relevant science (Fig. 6).

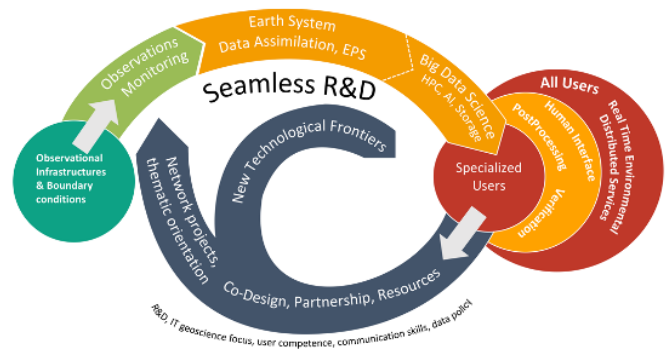


Fig. 6. Science for Services Journey from Ruti, et. al (2020), 10.1175/BAMS-D-17-0302.1 p. E23-35

The Hydrology and Cryosphere Coordination unit ensures that WMO can achieve the objectives of the WMO Strategic Operating Plan and meet the eight hydrological ambitions:

- a. No one is surprised by a flood;
- b. Everyone is prepared for drought;
- c. Hydroclimate and meteorological data support the food security agenda;
- d. High-quality data supports science;
- e. Science provides a sound basis for operational hydrology;
- f. We have a thorough knowledge of the water resources of our world;
- g. Sustainable development is supported by information covering the full hydrological cycle;
- h. Water quality is known.

Entry points for collaboration with GEWEX are:

1. Observation and Monitoring: Linkages between climate variability and water security planning at decadal and climate change time scales (Global Hydrological Status and Outlook System, or HydroSOS).
2. Modeling and Prediction: Linkages between climate and hydrologic systems for nowcasting and forecasting applications at sub-seasonal and seasonal time scales (integrating models; HydroSOS; validation/background data).

WCRP, GEWEX’s parent organization, coordinates international climate research and provides a reference framework for both individual researchers and national funding agencies. A review of WCRP and its programs in 2018 concluded that WCRP’s current structure is not able to meet the challenges of the future. This conclusion led to the WCRP publication of the new strategic plan for the period 2019–2028 in 2019. To meet the challenges and opportunities described in the strategy plan, WCRP will be modernized in order to be “fit-for-purpose” (Fig. 7).

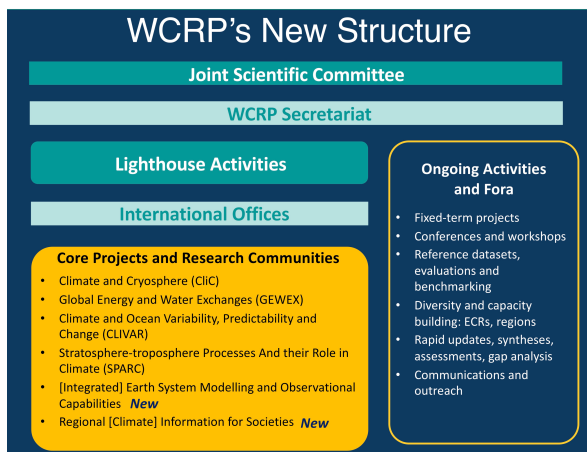


Fig. 7. WCRP’s New Structure

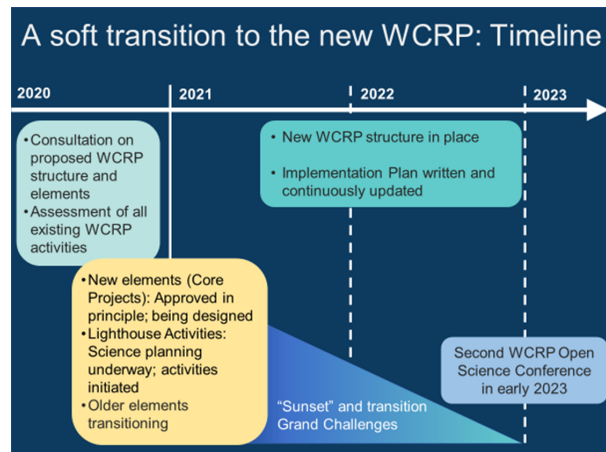


Fig. 8. Timeline WCRP’s soft transition

Fig. 8 shows the timeline of WCRP’s soft transition to the new structure. At its December 2020 meeting (JSC 41B), the Joint Scientific Committee approved the creation of two new Core Projects, Regional Information for Society and Earth System Modelling and Observational Capabilities, and five new Lighthouse Activities (LHAs). The LHAs are described in more detail in §1.4.

Progress was made with designing new elements related to WCRP’s science, scope and governance and for ways to engage with other WCRP activities and the required supporting arrangements. Additionally, WCRP established new collaboration agreements and refreshed existing ones e.g., Joint Statement with Future Earth, the USGCRP Seminar in February 2021, joint session planning with Future Earth and Belmont Forum for Sustainability Research + Innovation (SRI) Congress 2021. A start has been made with the organization of the second WCRP Open Science Conference in 2023 (OSC2023). One of the OSC2023 themes is the celebration of WCRP’s past success with a special focus on the results and advances that emerged from the WCRP Grand Challenges. A second theme will be to roll out and showcase the new WCRP, especially for Early Career Scientists and communities from the global South.



Two of WCRP’s core programs, the Climate and Cryosphere Project (CliC) and GEWEX, have the water and energy cycles in common. CliC serves as the focal point for climate science related to the cryosphere, its variability and change, and interaction with the broader climate system. CliC coordinates research in the Arctic, Antarctic, high-elevation mountain areas, and broad regions that experience snow, lake and river ice and permafrost.

CliC’s science is focused on:

- The role of the cryosphere in the climate system
- Improving observations of the cryosphere
- Dynamic and process understanding
- Predictions and projections of the cryosphere under climate change

CliC leads the WCRP Grand Challenge (GC) on Melting Ice and Global Consequences. Its main science question is: “How will melting ice respond to, and feedback on, the climate response to increasing greenhouse gases, and what will the impacts be?” Activities in 2020 include six Model Intercomparison Projects and nine joint projects and panels.

The coming period is dedicated to writing the CliC Strategic and Action Plan 2022–2031, including a new vision and mission statement. The four goals for this period are to:

1. Provide integrated assessments of global cryosphere change
2. Provide a forum for launching new activities aimed at addressing the priorities above
3. Leverage cross-disciplinary and international collaboration to address cryosphere priorities
4. Provide input and participate in WCRP Lighthouse Activities

CliC sees an opportunity to connect with GEWEX, and the GLASS Panel in particular, on science concerning the ecosystem and permafrost.

The mission of WCRP’s core program “Climate and Ocean–Variability, Predictability, and Change” (CLIVAR) is to understand the dynamics, interaction and predictability of the climate system with emphasis on ocean-atmosphere interactions. Its overarching goal is to build a society resilient to environmental changes.



CLIVAR’s Science Plan 2019–2028 identified three scientific priorities:

- Mechanisms of climate variability and change that require further investigation with the ultimate goal of better constraining the fluxes of energy and carbon in the climate system.
- Ocean processes that modulate climate variability and change for which open questions remain.
- Climate predictability challenges that exist over a broad range of space and time scales.

Apart from participating in the new WCRP LHAs and Regional Focal Point groups, publications and several online meetings and workshops, CLIVAR initiated the Research Focus (RF) on Tropical Basin Interaction (TBI) in March 2020. RF TBI aims to create a consensus on the mechanisms underlying TBI and how these contribute to predictability, and to promote research on how these interactions are affected by low-frequency climate variability and long-term

climate change. CLIVAR has planned workshops, meetings and summer schools on different topics in the near future. Furthermore, a roadmap to sustained observations of the Indian Ocean 2020–2030 (Indian Ocean Observing System 2, or IndOOS-2) will be launched. IndOOS-2 can provide a fit-for-purpose observing system that leads to improved weather forecasts, climate predictions and marine ecosystems understanding for the benefit of all. A new research focus is the Tropical Basin Interaction (TBI). Its main goal is to clarify the complex two-way interaction between the tropical basins and to quantify the benefit to climate prediction.

Plans for the coming period exist of new and, due to COVID-19 rescheduled meetings, workshops and summer schools. Additionally, the CLIVAR Atlantic regional panel will form the CLIVAR Atlantic Meridional Overturning Circulation (AMOC) Task Team, which is a follow-up on the sunsetting U.S. CLIVAR AMOC science team. The first activity is planned for 2021 and consist of a virtual workshop on assessing observational strategies.

The aim of CLIVAR AMOC is to:

1. To promote and coordinate international collaborations amongst observational and modeling studies
2. To coordinate international workshops on AMOC science and impact topics
3. To produce a summary report with identified priorities of the AMOC community
4. To improve data and product distribution from AMOC programs
5. To develop strategies for cost-effective, sustained monitoring of the AMOC (through an assessment of the observing system using e.g., Observation System Experiments)

Current CLIVAR-GEWEX collaboration exists on the Earth Energy Imbalance project and on Global Monsoons. Areas of interest to expand the collaboration are on the Earth Water Imbalance, Unified turbulence of the Atmospheric Boundary Layer over land, ocean and ice, process studies and observational requirements for extreme precipitation prediction and on several themes with the CLIVAR Climate Dynamics Panel.



The Coordinated Regional Downscaling Experiment (CORDEX) vision is to advance and coordinate science and application of regional climate downscaling through global partnerships. In 2020, new CORDEX simulations are visible on all Earth System Grid Federation (ESGF) index nodes worldwide and contributed to the Climate Model Intercomparison Project phase 6 (CMIP6). The CMIP6 protocol is expected to be published in May 2021.

Currently, there are 13 CORDEX Flagship Pilot Studies (FPSs). FPSs are intended to specifically tackle scientific questions for any given region of the world for which current regional climate models are still unable to reproduce the regional climate features adequately and result in actionable actions. Additionally, FPSs are encouraged to reach resolution at convection-permitting scales and address an end-to-end perspective e.g. extreme precipitation/events with large socio-economic impacts (location, intensity, frequency), water supply – drought (crops, health) and landslides (infrastructure).

A White Paper on future scientific challenges for CORDEX is expected to be published in May 2021 and will include elements addressing data and infrastructure, increasing complexity of Earth and finer resolution used to inform risks detailing Vulnerability, Impact and Adaptation (VIA). In time, CORDEX is expected to become part of the new WCRP “Regional Climate Information for Societies” (RiFS) home.



The Stratosphere-Troposphere Processes and their Role in Climate (SPARC) core program of WCRP has three main science themes:

- Atmospheric dynamics and predictability
- Chemistry and climate
- Long-term records for climate understanding

SPARC is organized through a bottom-up approach where activities are proposed by its community. All SPARC activities provide network opportunities centered on topical research and contribute to the United Nations Environment Programme (UNEP) Ozone Assessments and the CMIP project. Currently there are 18 activities that have a focus on one or more of the following three categories:

1. data evaluation e.g., Atmospheric Temperature Changes (ATC) and their drivers and DynVar on the Dynamics and Variability of the stratosphere-troposphere system;
2. model development e.g., Polar Stratospheric Clouds (PSC) characteristics improvement in Global global models and Atmospheric Composition and the Asian Monsoon (ACAM);
3. networking e.g., SPARC Reanalysis Intercomparison Project (S-RIP) project, which connects base research communities with operative centers and agencies around the globe, and the Stratospheric Sulfur and its Role in Climate (SSiRC) project, which provides a coordinated structure for individual activities already underway in different research centers.

The findings and advice of a strategy task team assigned with assessing current structure, strengths and weaknesses of SPARC are used to update SPARC's strategic plan and are summarized as follows:

- Activity structure works well
- Need to push opportunities to take on a whole-atmosphere approach
- Focused topics should still be encouraged
- Need a balance between top-down and bottom-up organization
- SPARC facilitates good climate research
- Encourage focused research activities in the context of Light House Activities
- Provide dynamical insights into modeling studies and technical support for model analysis
- Could develop a set of diagnostics for dynamics
- SPARC supports policy-relevant climate sciences
- Maintain and advance long-term climate records for large assessments (IPCC, WMO/UNEP Ozone, etc.) and mission planning
- Address local impacts of climate change
- Geoengineering (i.e., radiation management)

Synergy between SPARC and GEWEX's GASS Panel offers ample opportunities for collaboration e.g., SPARC Network on Assessment of Predictability (SNAP) on Sub seasonal to Seasonal prediction and the Stratospheric And Tropospheric Influences On Tropical Convective Systems (SATIO-TCS) project on tropical convection. Approaching RHPs from a SPARC point of view can lead to other openings for collaboration.

After the 40th JSC meeting in May 2019, a Task Team on Regional Activities (TTRA) was appointed. TTRA was tasked to develop a concrete work plan and to propose implementing structures. The new WCRP home Regional Information for Society (RifS) is in the process of being established. The structure of RifS is based on four Building Blocks (BB):

- BB1. **Regional Climate Science** with a major focus on regional coordination for climate change (including dynamical and statistical modelling + CORDEX)
- BB2. **Global Information for Regions** with a major focus on the harmonization of multiple sources
- BB3. **Prediction** with a focus on seasonal to decadal timescales
- BB4. **Dialogue with Society** e.g., research involving stakeholder context, co-production and communication

The Working Group on Building Blocks (WGBB) has been assigned the development of a draft science plan, which should be completed before the JSC 42 meeting in 2021. The recently formed Interim Coordinating Group (ICG) is asked to draft a White Paper to be presented at JSC 42 meeting in 2021. Key questions that need to be addressed focus on the RifS niche, relationships [diversity, (research) partners and stakeholders], structure (governance and terms of reference), necessary resources and a timeline and roadmap indicating key milestones.

Models, data and observations are part of many WCRP entities (Fig. 9). To address the overall coordination mechanism across all models, data and observations activities within the program, it was decided at the JSC-41B meeting in 2020 to start with the establishment of the Earth-System Modelling and Observation Capability (ESMOC) core project, the second new WCRP home.

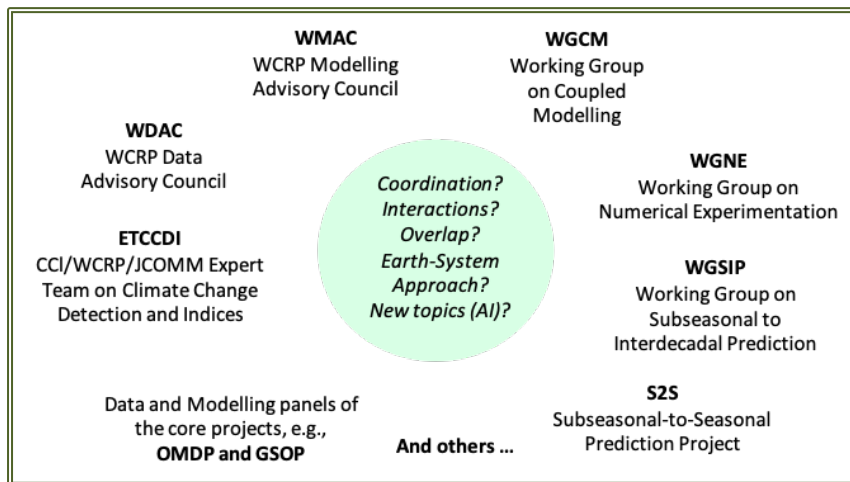


Fig. 9 Models, data and observations within the WCRP family

ESMOC’s goals and outcomes are outlined in terms of:

1) Research:

- * Seamless and value-chain model-data-observation approach
- * Across Earth system components, fundamental and applied disciplines, time and spatial scales, infrastructures
- * Optimize model development
- * Formulate observational requirements to monitor, understand and predict the climate system

- 2) Infrastructure:
 - * Integrated modeling and data infrastructures
 - * Data policy, protocols and standards
- 3) Access and communication:
 - * Share best practices, data, knowledge, opportunities
 - * Efficient communication across WCRP constituencies, communities, external partners and stakeholders
 - * Particular attention to engagement, equal access and inclusion of the “global south”
- 4) Partnerships and organization:
 - * Identify stakeholders, scientific ambition and resourcing needs
 - * Develop risk mapping and mitigation measures
 - * Remove fragmentation, duplications and suboptimal aspects in the program

Some of the challenges ESMOC faces in the coming period are to:

- adopt a common ground and to ensure buy-in and merging of the scientific communities;
- keep current successful activities with their own priorities and momentum intact;
- ensure successful collaboration with existing model and data panels;
- define high-level contributions and research priorities e.g., understanding and reduction of systematic errors in Earth system models;
- future role of data science and machine learning;
- take into account value-chain and seamless approaches.

1.3 GEWEX Interactions with Sponsors and Partners

On 27 January 2021, the newly-elect U.S. president Joseph Biden issued an executive order on tackling the climate crisis nationally and internationally, putting the climate crisis at the center of U.S. foreign policy and national security and taking a government-wide approach to the climate crisis. The National Aeronautics and Space Administration (NASA) is poised to help the White House National Climate Task Force address the most pressing climate change issues today through its long-term observations of Earth, providing insight into how the planet is changing, efforts to contribute to sustainable aviation and nurturing partnerships with the private sector.

The operating and unto 2023 planned NASA Earth Fleet consists of four primary and 13 extended operations. In addition, there are three operations in the (pre)formulation and nine in the implementation phase. The latter category includes Landsat 9, which is expected to launch in September 2021. Landsat9 is designed and operated to repeatedly observe global land surface at a moderate scale that shows both natural and human-induced change. Earlier Landsat operations showed that over the last 35 years conditions of the water quality of 33% of U.S. rivers has changed relating to the amount of sediment, algae and dissolved organic carbon in water. Hotspots where changes are found are often located near dams and urban areas.

The NASA Energy and Water Cycle Studies (NEWS) shifted to two larger “Water and Energy Cycle Process Teams”: i) Untangling Changes in the West Pacific Water Cycle (Kummerow, et al.) and ii) Global and Regional Water and Energy Variations Under a Changing Climate (L’Ecuyer, et al.). Other tent poles in the effort to tackle the climate crisis are the Justice, Equity, Diversity, and Inclusion (JEDI) Group and the 2017 Decadal Survey. The goal of the

JEDI group is to build a diverse, equitable, inclusive, accessible and just environment for marginalized communities within the Earth science community by identifying, proposing and implementing anti-racist actions. The 2017 Decadal Survey:

- emphasizes partnerships and innovation
- identifies key questions and observations for:
 - Climate variability and change
 - Weather and air quality
 - Hydrological cycles and water resources
 - Ecosystems and natural resource management
 - Solid Earth dynamics and hazards
- Five Designated Observables (Fig. 10):
 - Aerosols (A)*
 - Clouds, Convection and Precipitation (CCP)*
 - Mass Change (MC)*
 - Surface Biology and Geology (SBG)
 - Surface Deformation and Change (SDC)*
- Competed Earth System Explorers, an Incubation element, and Earth Venture Continuity

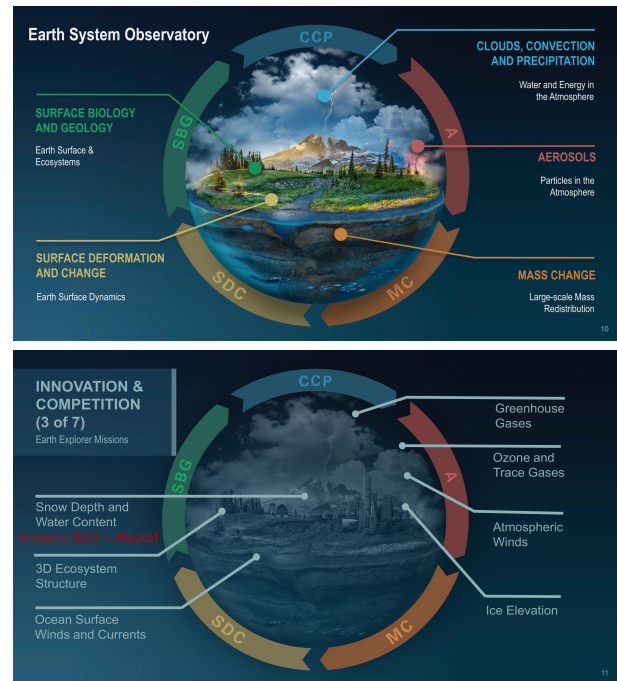


Fig. 10. 2017 Decadal Survey: Five Designated Observables

(*Indicates that the observable addresses the most important climate variability and change questions)

The Centre National d'Études Spatiales (CNES) is the French government space agency. Its past, present and future Earth Observation (EO) programs are linked to the principal geophysical cycles and based on three pillars: Infrastructures, Research and Downstream programs. The CNES EO program uses a consistent set of actions aimed at covering all facets of the Earth system using a combination of satellite, in situ and model data to guide Research and Technology actions (R&T) and the development of downstream applications (Fig. 11).

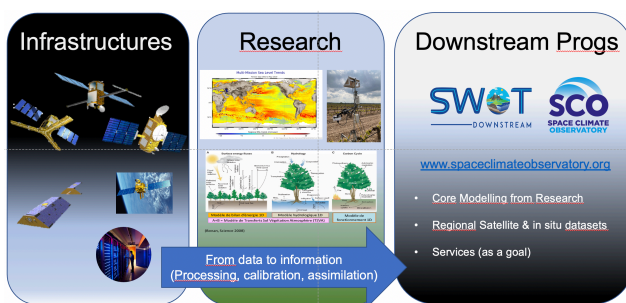
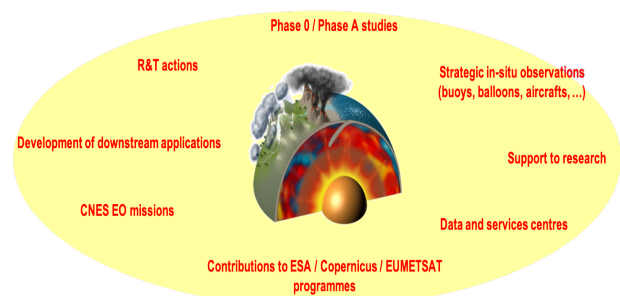


Fig. 11. CNES EO Program



CNES projects involve large infrastructures, high-tech instrumentations and international partnership. They require expertise on EO measurements (understanding, processing, calibration and validation) and have a strong applicative potential. In addition to contributing to the Copernicus Sentinel program, CNES currently has approximately 18 EO missions either operational or in development in collaboration with various partners, e.g., EUMETSAT, NASA, ESA, etc. One of its downstream programs is “Surface Water and Ocean Topography (SWOT)

Downstream”. SWOT downstream prepares the use of new measurements, builds a database of satellite information on water, prepares future hydrological, coastal and oceanographic services and integrates SWOT’s high-resolution capabilities into products and models.

The CNES Hydoweb service is a water level monitoring time series beginning in 1992. This service continuously improves the accuracy of data and size of thousands of rivers and lakes worldwide through 11,000 virtual stations. It’s linked with ESA’s Climate Change Initiative on Lakes and the Copernicus Global Land Service. The Theia Land Data Centre is a French national inter-agency organization designed to promote the use of space observation images of land surfaces with contributions from over 20 scientific expertise centers on areas such as soil moisture, evapotranspiration, irrigated surfaces and snow-covered surface and snow altitude.

Initiated by CNES, the Space Climate Observatory (SCO) International Initiative addresses the need to step up international coordination for accurate assessment and monitoring of the consequences of climate change from observations and numerical models. By conceiving of methodologies that combine various data sources to provide scenarios for action, the SCO aims to become an important tool for decision-making on preparedness, adaptation and resilience to the impacts of climate change at the local level.

Copernicus is the European Union’s EO program implemented in partnership with member states, ESA, EUMETSAT and ECMWF, EU Agencies and Mercator Océan. Its core objective is to provide reliable access to high-quality climate data derived from a set of dedicated satellites (Sentinel families) and contributions from existing commercial and public missions and in situ systems. The Copernicus services transform the satellite and in situ data into value-added information by processing and analyzing the data through their Climate Data Store (CDS). These value-adding activities are streamlined through the six thematic streams of Copernicus services: Atmosphere, Climate Change, Emergency, Land, Marine and Security. Implemented by ECMWF, the Copernicus Climate Change Service (C3S) is committed to providing authoritative information about the past, present and future climate in Europe and around the world. It offers free and open access to climate data and tools based on the best available science through the CDS to support adaptation and mitigation policies of the European Union and strive to help the more than 82,000 users achieve their goals in dealing with the impacts of climate change (Fig. 12).

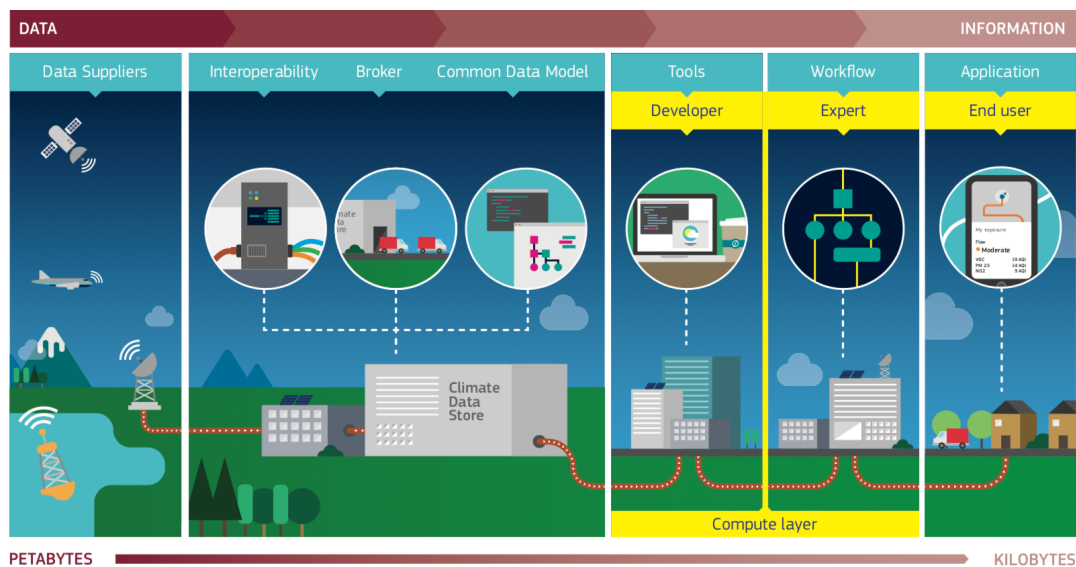


Fig. 12. Copernicus Climate Change Service (C3S)

Especially with satellite data, a lot of effort is put in the curation of Essential Climate Variables (ECVs) as defined by the Global Climate Observing System (GCOS). Currently, the CDS catalogue holds 22 ECVs and the ambition is to increase this to 35 in the next few years. The motivation for ECV requirements is based on:

- top-down requirements based on climate science or climate monitoring principles like closing the budget e.g., permafrost-related variables, which are under-sampled and under-characterized in the CDS;
- requirements driven by internal use of ECVs for both C3S and ECMWF as a whole e.g., land surface variables or soil carbon;
- requirements emerging from the +82,000 users of CDS.

In the second half of 2019, the ERA-interim reanalysis was superseded by ERA5, a full-observing-system global reanalysis, which provides hourly estimates of a large number of atmospheric, land and oceanic climate variables. Preliminary daily updates of the data set (1979 to present) are available to users within 5 days of real time. The preliminary ERA5 data set from 1950 to 1978 is also available in the CDS. ERA5-Land is a reanalysis data set covering the period from 1981 to 2–3 months before the present and provides hourly high-resolution information of surface variables over several decades at ~9 km grid spacing. The plans for reanalysis in the coming years are:

- 2021–2022: Extend ERA5 further back to 1940 or before.
- 2024–2026: Production of ERA6
 - Coupled ocean, high resolution reanalysis
 - EUMETSAT reprocessed data
 - C3S satellite data rescue
 - ERA6L with enhanced land data assimilation
- 2021–2025: Effort to maintain regional reanalysis
 - Pan-Arctic, Europe
 - Back extension

All data set products and tools to manipulate the data are subject to quality assurance procedures. Enough information is available for users to determine if a certain product is fit for purpose. The whole infrastructure is used both to underpin the “state of the climate” publications released annually in April and in many sector applications, e.g., biodiversity, disaster risk reduction, health, tourism, and more. The sector underpinning many projects in climate adaptation is the interactive application for Climate & Hydrology Impact Indicators from 1970 to 2100. This data set provides water variables and indicators based on hydrological impact modeling, forced by bias-adjusted regional climate simulations from the European CORDEX. The data set contains ECV data in the form of daily mean river discharge and a set of Climate Impact Indicators (CIIs) for both water quantity and quality. Data on surface runoff is not readily available and might be a suitable topic to work on jointly with GEWEX.

Alongside applications mostly focused on protection, ECMWF supports the Copernicus Emergency Management Service (CEMS) in the operational setup. CEMS supports all actors involved in the management of natural or manmade disasters by providing geospatial data and images for informed decision making. The Early Warning and Monitoring component offers anticipatory critical geospatial information at European and global level through continuous

monitoring and forecasts for floods, droughts and forest fires through the following systems: the European and Global Flood Awareness System (EFAS; GloFAS), the European Forest Fire Information System (EFFIS) and the European and Global Drought Observatory (EDO; GDO).

The mission of the Earth and Environmental Systems Sciences Division (EESSD) of the U.S. Department Of Energy (DOE) is to enhance the seasonal to multi-decadal scale predictability of the Earth system. Its vision is an improved capability for Earth system prediction on seasonal to multi-decadal time scales to inform the development of resilient U.S. energy strategies. In order to inform the development of advanced solutions to the Nation’s U.S.’s energy challenges, it uses long-term field experiments, DOE user facilities, modeling and simulation, uncertainty characterization, best-in-class computing, process research, and data analytics and management. EESSD is organized in three research activities:

1. Atmospheric Research, which addresses two major areas of uncertainty in Earth system models: the interdependence of clouds, atmospheric aerosols and precipitation that in turn influences the radiation balance
2. Environmental System Science (ESS), which goal is to advance an integrated, robust and scale-aware predictive understanding of terrestrial systems and their interdependent microbial, biogeochemical, ecological, hydrological and physical processes
3. Earth and Environmental Systems Modeling program (EESM), which investments focus on model development and analysis, and understanding the role of multi-sector interactions with the physical-human system. EESM program areas are:
 - a. Earth System Model Development (ESMD), which envision developing Earth system models, i.e., the Energy Exascale Earth System Model (E3SM) and its subcomponents, to address the grand challenge of actionable predictions of the changing Earth system, with an emphasis on the most critical scientific questions facing the nation and DOE
 - b. Regional Global Modeling Analysis (RGMA), which goal is to enhance predictive and process level understanding of variability and change in the Earth system by advancing capabilities to design, evaluate, diagnose and analyze global and regional earth system models informed by observations
 - c. MultiSector Dynamics (MSD) aims to explore the complex interactions and potential co-evolutionary pathways within the integrated human-Earth system, including natural, engineered and socioeconomic systems and sectors (Fig.13).

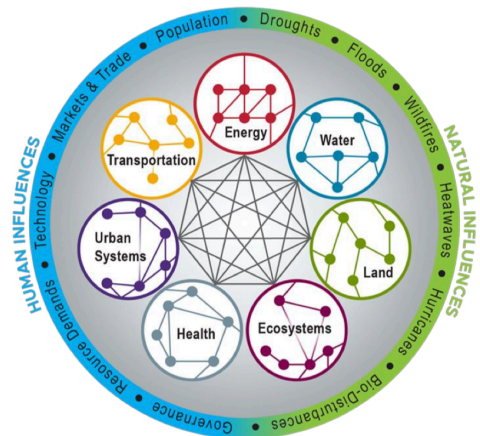


Fig. 13. MultiSector Dynamics (MSD) Program area

Potential areas for collaboration between DOE and GEWEX are:

- Using data from Atmospheric Radiation Measurement (ARM) upcoming observational activities and field campaigns, which are:
 - Surface Atmosphere Integrated Field Laboratory (SAIL; September 2021–June 2023) focused on atmospheric and land-atmosphere interaction processes that impact mountain hydrology
 - Tracking Aerosol Convection Interactions Experiment (TRACER; October 2021–September 2022) focused on aerosol-cloud interactions and deep convection

- Large-Eddy Simulation (LES) ARM Symbiotic Simulation and Observation (LASSO), which enhances ARM observations by using LES modeling to provide context and a self-consistent representation of the atmosphere surrounding the Southern Great Plains (SGP) atmospheric observatory
- DOE hydroclimate modeling and observational activities addressing water in mountainous regions e.g., Watershed Scientific Focus Area (SFA)
- Engagement in several modeling efforts e.g., HyperFACETS (drought/snowpack loss), WACCEM (water cycle and climate extremes) and Calibrated and Systematic Characterization, Attribution and Detection of Extremes project (CASCADE)
- MultiSector Dynamics Community of Practice.

The European Space Agency (ESA) and GEWEX share an interest in fostering robust Earth Observation (EO) capabilities. In November 2020, ESA and GEWEX jointly organized the Earth Observation for Water Cycle Science Workshop. Due to COVID-19, the workshop took place online instead of in Versailles, France.

At this time, ESA has 16 satellites in operation, 38 under development and 14 in preparation, including science Earth explores like Aeolus (wind, 2018 to present), Cryosat (ice, 2010 to present), SMOS (water, 2009 to present) and SWARM (magnetic field, 2013 to present). Future Earth Explorers include EarthCare (clouds, aerosols and radiation, 2023), Biomass (biomass estimates, 2023), FLuorescence EXplorer (FLEX; vegetation fluorescence, 2024), Far-Infrared Outgoing Radiation Understanding and Monitoring (FORUM; Earth's radiation budget, 2027/28) and Harmony (key aspects of ocean, ice and land dynamics, 2031/32).

The European Copernicus Programme is the global leader in Earth Observation and an example of excellent cooperation between the European Commission and ESA. Daily, around 250 TB of new EO data is disseminated to society which benefits European interests, science and applications and boosts European competitiveness and technological innovation. The Copernicus Sentinel Expansion missions (Fig. 14) will support the European Green Deal, a set of policy initiatives by the European Commission with the overarching aim of making Europe climate neutral in 2050.

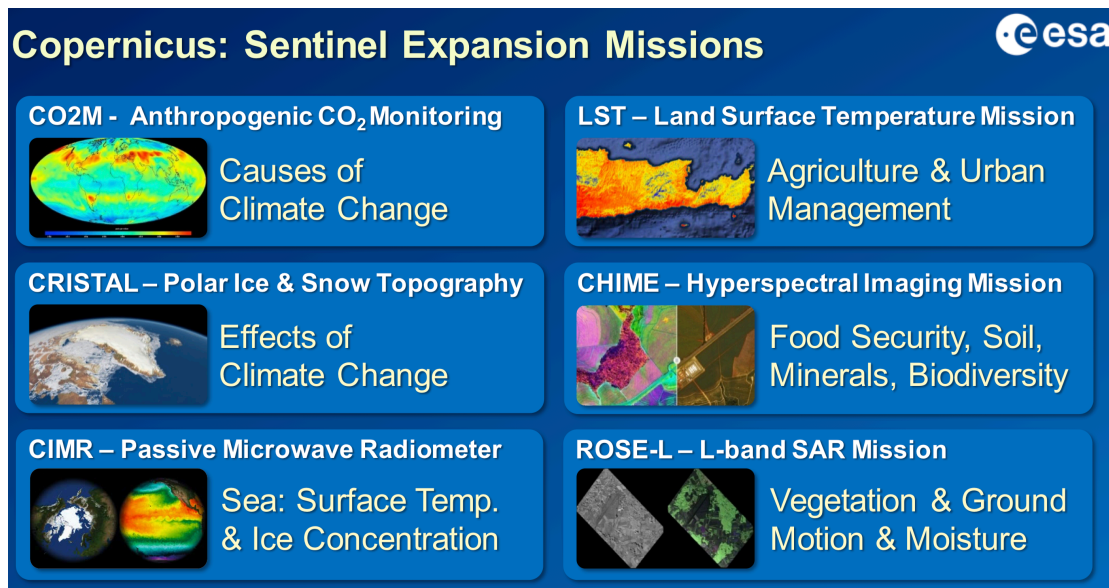


Fig. 14. Copernicus Sentinel expansion missions supporting the European Green Deal

ESA’s four science clusters: Polar Science, Ocean Science, Carbon and Water Cycle Science, offer research opportunities and innovative scientific studies. The collaborative research actions bring together different expertise, data and knowledge from different projects across Europe and beyond, adopting open science practices and tools. The ESA Earth System Science Hub facilitates these community networking activities and scientific collaboration, which maximizes the impact of novel technologies and cloud computing capabilities in science.

The priorities of ESA Water Cycle Science cluster focus are:

- new generation of high-resolution, consistent products and data sets;
- water cycle connections to human activities, food systems and ecosystems;
- climate adaptation, hydro-climatic extremes and natural hazards;
- hydrological cycle in mountain regions;
- regional water cycle e.g., the Baltic, Pannonian and Mediterranean;
- Digital Twin Earth showing an advanced reconstruction of the hydrological cycle <1 km

The 2020 cooperation agreement between ESA and the new Research and Innovation Framework Programme of the European Union (EC-RTD) combines ESA FutureEO, a new Science and Innovation Earth Observation Programme, with EC-RTD’s Horizon Europe, a new European Research and Innovation Framework Programme. This collaboration will lead to new information and communication technology, cloud computing, artificial intelligence, interdisciplinary and open science, enhanced models and predictions and in situ networks/citizen data prospects.

The Hydrology Thematic Exploitation Platform (Hydro-TEP) is part of a larger TEP ecosystem developed and validated with the support of ESA. Hydro-TEP is a collaborative and open platform for large data volume processing and sharing for Integrated Water Resources Management (IWRM). It supports algorithm development, sharing of data, tools and know-how. The thematic applications include hydrological modeling, flood and small water bodies mapping, water quality and water level.

ESA EO programs in support of international development include:

- EO Africa, whose objective is to develop an African-European research and development partnership to facilitate the sustainable uptake of EO and related space technology in Africa
- Earth Observation for Sustainable Development (EO4SD) is an ESA initiative (2016–2023) that aims to achieve a step increase in the uptake of satellite-based environmental information in the International Financing Institutions’ (IFIs) regional and global programs.
- Space in support of International Development Assistance (Space for IDA), a partnership with the World Bank and the Asian Development Bank. Its objective is to grow the wide-scale, systematic use of satellite EO as a “best-practice” source of environmental information, integrated in the working practices and finances for all phases and activities of development assistance operations.
- ESA Climate Change Initiative (CCI) projects provide long-term satellite climate data sets to support the United Nations Framework Convention on Climate Change (UNFCCC). CCI comprises 23 ECV projects, two budget closure projects, a data support project and a climate modeling project.

The European Commission has entrusted EUMETSAT with exploiting the four Sentinel missions (Sentinel -3, -4, -5 and -6) dedicated to the monitoring of atmosphere, ocean and climate on its behalf. These missions are complementary with EUMETSAT’s METEO missions and fit into the long-term commitment of EUMETSAT to run multi-satellite programs.

EUMETSAT contributes to the “GEO ring”, an international cooperation between partner organizations providing observations from several next generation missions. Its long-term objectives are:

- utilization of past, current and future geostationary observations for climate monitoring;
- collection of knowledge and experience of the space agencies to create most credible satellite data record for climate science and services;
- generation of quality-controlled, recalibrated and uncertainty-characterized Fundamental Data Records (FDRs) for each individual geostationary platform addressing all spectral channels;
- generation of a quasi-global Fundamental Climate Data Record (FCDR) derived from the individual FDRs, which could be the ISCCP L1g product;
- utilization of modern infrastructure, such as cloud computing, to enable distributed data processing and guaranteeing easy access to the data for users worldwide.

EUMETSAT and ECMWF have joined forces to set up “The European Weather Cloud”, a distributed cloud computing infrastructure to serve the European Meteorological infrastructure and its users. It aims to become the cloud-based collaboration platform for meteorological application development and operations in Europe and contributes to the digital transformation of the European Meteorological Infrastructure.

Looking forward, the Multi-viewing, Multi-channel, Multi-polarization Imaging (3MI) instrument is scheduled to launch on Meteorological Operational Satellite-Second Generation (MetOP-SG) at the end of 2022. It’s the first operational dedicated aerosol mission with advanced cloud observing capabilities. At that same time, the Ice Cloud Imaging (ICI) instrument will also be expected to launch on MetOP-SG. It is the first operational dedicated

ice-cloud imaging mission and offers the capabilities for snowfall detection and quantification and enables reducing uncertainty in General Circulation Model parameterization.

The Meteosat Third Generation (MTG) is scheduled to start operations in 2023 (MTG-I) and 2024 (MTG-S). It will provide an unprecedented 4-D weather monitoring capability through an evolution of the imaging service, a new lightning imaging service and a new atmospheric sounding service providing measurements in the infrared and ultraviolet and will enrich input to numerical weather prediction data assimilation and the future derivation of quantitative products (Fig. 15).

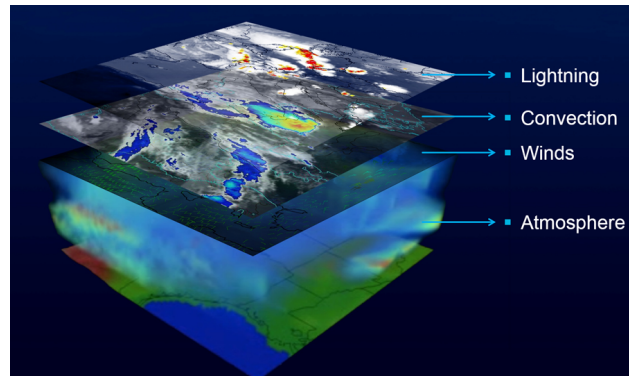


Fig. 15. The MEOSAT Third Generation (MTG) data

To foster activities, EUMETSAT plans to revive the SCOPE-CM IOGEO* project under a new name: *Geostationary ring of meteorological satellites FCDR for Climate (GeoClim)*. This project can support the needs of many “geo ring” FCDR users for global ECV data records, including GDAP’s ISCCP-NG project. In addition, EUMETSAT offers particular support to ISCCP-NG by addressing best possible calibration, cross-calibration and Level-1 data availability for usage. In addition, EUMETSAT offers a potential use of the European Weather Cloud processing via specific research projects e.g., ISCCP-NG can be a candidate also in connection with the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) that will do operations in their hosted processing.

Other areas for collaboration between EUMETSAT and GEWEX are:

- Microwave exploitation in Polar regions: radiative transfer models have limitations over the Poles, snow emissivity issue. How can international research be accelerated?
- Synergies across measurements: soon several instruments will be launched on EUMETSAT Polar System-Second Generation (EPS-SG) and MTG payloads. Microwave and millimeter scale observations will be available to characterize the atmospheric water cycle. How can the link to GEWEX research be improved?
- Aerosols and the water cycle: new polarization measurements will increase the information on aerosols. This may help to close the gap between chemistry and the water cycle.
- In relation to Destination Earth, i.e., Digital Twins, Digital Earth, etc., research on how observations will be integrated into the Digital Earth framework needs to be boosted. The main goal is not just to have a 1-km scale Earth system model, but also to develop the necessary research on how to integrate the existing observations in such a system (i.e., data assimilation, machine learning applications) and how to plan future missions for such a system.

The Japanese Aerospace exploration Agency (JAXA) implements studies that contribute to science and/or have societal benefits. JAXA’s research used to be conducted based on individual satellite missions. Today, research includes new activities such as cross-sectional projects among satellite missions, whether combined with numerical models or not. Processes of climate change in response to greenhouse gasses and radiative forcing are also important in understanding the issue of global warming and predicting climate in the future. Interaction

* Sustained and COordinated Processing of Environmental satellite data for Climate Monitoring (SCOPE-CM) Inter-calibration of passive imager observations from time-series of geo stationary satellites (IOGEO)

between the two systems, radiative forcing and interactions with climate systems are complicated and many feedback mechanisms among individual variables are involved.

JAXA's future Advanced Land Observing Satellite (ALOS) series missions include the ALOS-3 (2021) with improved ground resolution (0.8 m) and wide-swath (70 km) used for disaster mapping and the ALOS-4 L-band synthetic aperture radar (SAR) satellite (2022), which will observe and monitor disaster-hit areas, forests and sea-ice. In addition, ALOS-4 will also challenge new areas such as monitoring infrastructure displacement. JAXA's Global Change Observation Mission (GCOM) consists of two satellite series. Global Observation Satellite for Greenhouse gases and the Water cycle (GOSAT-GW) is JAXA's next generation satellite to monitor the greenhouse gases like carbon dioxide in the Earth's atmosphere. GOSAT-GW will have two missions: i) greenhouse gas observation for Japan's Ministry of the Environment and the National Institute for Environmental Studies, and ii) water-cycle observation for JAXA. The Earth Cloud, Aerosol and Radiation Explorer (EarthCARE) mission, a joint venture between ESA and JAXA, is expected to launch in 2022. EarthCARE will employ high-performance lidar and radar technology with the objective of delivering unprecedented data sets to allow scientists to study the relationship of clouds, aerosols and radiation at accuracy levels that will significantly improve our understanding of these highly variable parameters. The GCOM-Climate "SHIKISAI" (GCOM-C) conducts surface and atmospheric measurements related to the carbon cycle and radiation budget, such as clouds, aerosols, ocean color, vegetation and snow and ice. The GCOM-Water (GCOM-W) observes changes in water circulations. The Advanced Microwave Scanning Radiometer 2 (AMSR2) on-board the GCOM-W satellite observes precipitation, vapor amounts, wind velocity above the ocean, sea water temperature, water levels on land areas and snow depths. Version 4 products for sea surface temperature (SST) and sea surface wind speed were released in October 2020. Observations show that SST decreases correspond to passes of typhoons. JAXA's data record of spaceborne precipitation radars is over 20 years. At this time, a feasibility study for the next generation precipitation radar is carried out and discussion with NASA for collaborations in NASA's Aerosol, Cloud, Convection and Precipitation (ACCP) study are ongoing. Fig. 16 shows an overview of current and future Japanese Earth observation satellites.

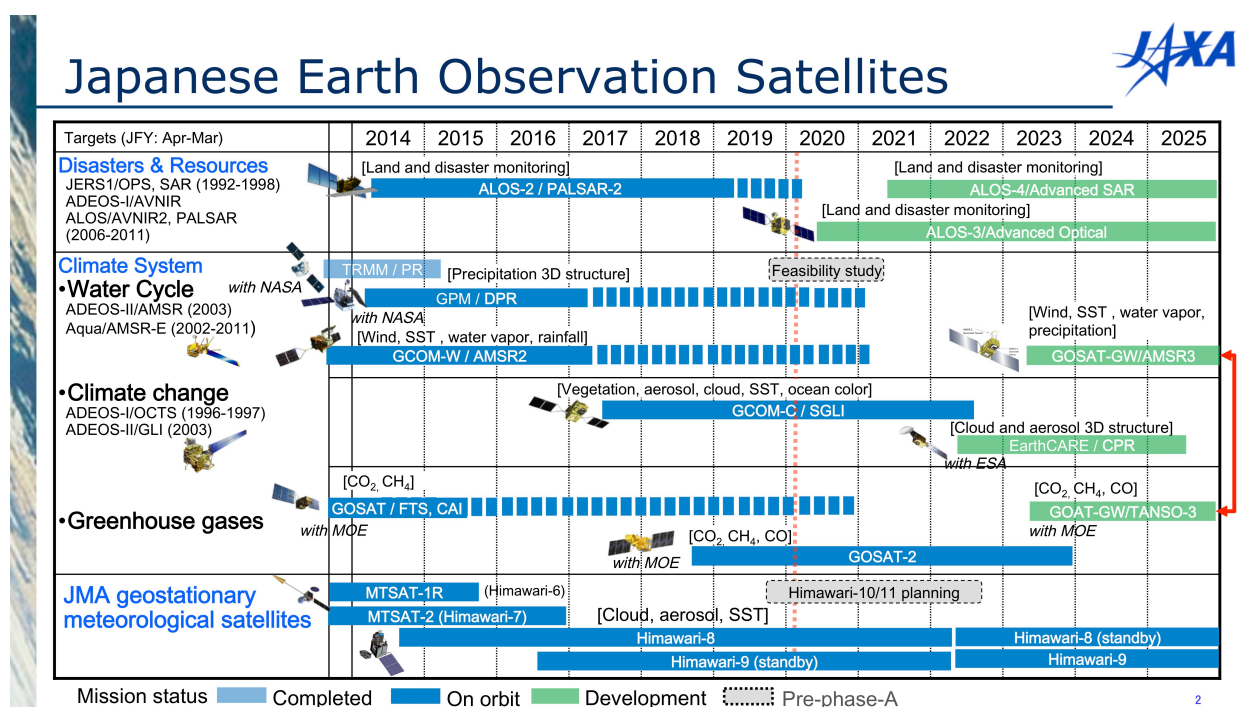


Fig. 16. Japanese Earth observation satellites

Recently, JAXA has begun to operate the “[JAXA Climate Rainfall Watch](#)”-website. It’s a website for statistical variables such as climatology and extreme/drought indices in some time scales of daily to monthly based on Global Satellite Mapping of Precipitation (GSMaP) gauge-calibrated near-real-time product. Together with the University of Tokyo, JAXA developed “Today’s Earth”, a global terrestrial hydrological simulation system. “Today’s Earth” can visualize risk indices in terms of return period as well as various hydrological products.

Areas for collaboration between JAXA and GEWEX can be found in global in situ observations for data validation and integration e.g., including JAXA’s satellite data in GEWEX’s inter-comparison and evaluation activities. More specifically, JAXA is interested in research aimed at estimating the water budget at high latitudes in large areas by combining satellite, model and in situ observations to address both snow and rain (ice and water).

The mission of the National Oceanic and Atmospheric Administration (NOAA) is to understand and predict changes in climate, weather, oceans and coasts; to share that knowledge and information with others and to conserve and manage coastal and marine ecosystems and resources. NOAA’s organizational structure consists of five line-offices (Research, Weather, Satellites, Oceans and Fisheries), six laboratories and four programs. One of its programs is the Climate Program Office (CPO), whose mission is to advance scientific understanding, monitoring and prediction of climate and its impacts to enable effective decisions. CPO has three major division, namely: i) Earth System Science and Modeling (ESSM), ii) Climate and Societal Interactions and iii) Communication, Education and Engagement. Highlights of CPO research are:

- process studies and field campaigns e.g., Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ; understanding wildfire smoke emission and chemistry), Atlantic Tradewind Ocean–Atmosphere Mesoscale Interaction Campaign (ATOMIC; understanding upper ocean processes and shallow convection in the Tropical Atlantic Ocean), the Alaskan Layered Pollution and Chemical Analysis (ALPACA) and COVID-19 related measurements (understanding urban atmosphere)
- Climate Process Teams (CPT) to speed up the improvement of coupled models, data assimilation systems and model components
- process-level diagnostics to accelerate model development. The new Modeling, Analysis, Predictions and Projections (MAPP; fiscal year 2021–2023) will particularly focus on open and coastal ocean systems, atmospheric chemistry and land surface and ecosystem processes
- explaining climate extremes: six projects on extremes, variability and climate change, including heat waves, cold air outbreaks, extreme El Niños, stratosphere and winter extremes, droughts and marine heat waves
- data set development and linking observations to modeling
- CPO Land/Hydrology research mainly supported by MAPP to:
 - improve drought understanding, monitoring and outlooks via the National Integrated Drought Information System (NIDIS)
 - improve the land component of climate models via CPTs
 - COM data set developments

One of the priorities of the NOAA Oceanic and Atmospheric Research (OAR) division is the Precipitation Prediction Grand Challenge (PPGC). Its strategic goal is to provide more accurate,

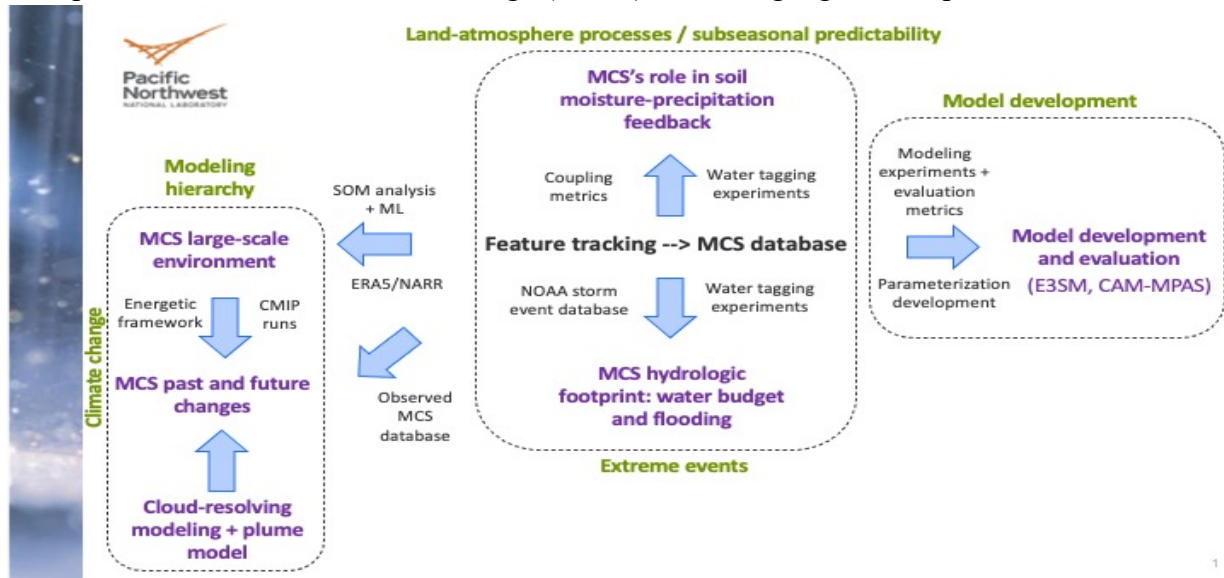


Fig. 17. PNNL Research on Mesoscale Convection Systems (MCS)

reliable and timely precipitation forecasts across timescales from weather to subseasonal-to-seasonal (S2S) to seasonal-to-decadal (S2D). GEWEX can help advance the PPGC initiative by connecting PPGC to GEWEX activities (e.g., current or planned projects related to precipitation; large observational data sets; potential partners) and by jointly plan and conduct research to address the precipitation challenge (e.g., field experiments, modeling experiments).

The Pacific Northwest National Laboratory (PNNL) is interested in Mesoscale Convection Systems (MCSs) because they are responsible for a lot of extreme precipitation worldwide, are a big driver of the large-scale circulation and because only a small number of climate models handle MCS well. PNNL research on MCS (Fig. 17) started out with developing ‘Feature Tracking’ as a means to track MCSs in databases, whether they come from radar or satellite data or in climate models. After developing the ‘Feature Tracking’- algorithm, the focus became the development of MCS databases, some of which are high-resolution, such as hourly, 4 km-resolution radar data over the U.S. Recently, PNNL developed a global MCS hourly, 10 km-resolution database over a period of 20 years based on satellite data. PNNL activities are aimed at looking at land-atmosphere processes and subseasonal predictability.

For instance, combining ‘Feature Tracking’, MCS database and water tagging experiments with coupling metrics shows MCSs’ role in soil moisture-precipitation feedback, and when combined with NOAA’s storm event database allows to look at the MCS hydrologic footprint. The latter includes the water budget associated with MCSs and understanding the contribution of MCSs to flooding. ‘Feature Tracking’ and the MCS database gives insight into historical changes in MCS and the large-scale environment that support MCSs. PNNL uses cloud-resolving models and developed a multi-column plume model to gain knowledge of how MCSs might change in the

future. Additionally, ‘Feature Tracking’ and the MCS database help evaluate how well climate models simulate MCSs, as well as improve and develop those models.

The Intergovernmental Hydrological Programme (IHP) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) aims to advance hydrological knowledge by supporting scientific research programs and capacity building activities. Water connects and is at the center of UNESCO’s Sustainable Development Goals and other agendas. Freshwater is a key resource for human health, prosperity and security. It’s essential for poverty eradication, gender equality, food security, and the preservation of ecosystems.

The main objective of IHP’s current, eighth phase (IHP-VIII, 2014–2021) is to put science into action required for water security. IHP's eight phase focuses on six thematic areas: water-related disasters and hydrological changes; groundwater in a changing environment; addressing water scarcity and quality; water and human settlements of the future; ecohydrology, engineering harmony for a sustainable world; and water education, a key to water security (Fig. 18).

By bringing innovative, multidisciplinary and environmentally sound methods and tools into play, while fostering and capitalizing on advances in water sciences, IHP acts at the science-policy nexus to help meeting today’s global water challenges.



Fig. 18. The six thematic areas of IHP VIII (2014-2021)

Looking forward, the priority areas of IHP’s ninth phase, “*Science for a Water Secure World in a Changing Environment*” from 2022–2029, are:

- Scientific research and innovation
- Water education in the fourth industrial revolution
- Bridging the data-knowledge gap
- Inclusive water management under conditions of global change

- Water governance based on science for mitigation, adaptation and resilience

Improvement of the collaboration between IHP and GEWEX can be realized by putting out a Call for a joint expert meeting consisting of hydrologists, marine scientists, cryosphere, sediment and climate experts. Other options are to write an action plan to develop a comprehensive scientific understanding of the Source-to-Sea phenomena incorporating the cryosphere, the terrestrial hydrological water cycle, sediment and erosion processes and deposition in littoral zones, deltas and coasts and its interaction with the ocean water or to revisit world water balance and interconnections.

1.4 GEWEX Outreach and Capacity-Building Activities

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 in a Monsoon Panel (MP) and three regional Working Groups (WGs), the Asian-Australian Monsoons, American Monsoons and African Monsoons WG. The WGs are relatively flexible to organize themselves with the guidance of the MP and are tasked with identifying priority areas for targeting advances. MP is reliant on the efforts carried out in the WGs.

During this reporting period, activities and contributions to the working groups stagnated. Regional contributions slowed down due to little financial support or incentives to contribute, exacerbated by COVID-19 as members had to cope with their country's situation. In addition, in the case of the WG on African Monsoons, the loss of their lead member, Francoise Guichard, significantly impacted activities. MP activities centered on updating the Terms of References and Working Plan and coordinating the contributions to the *GEWEX Quarterly* and CLIVAR special issues. Discussion within MP on the problems with the WG suggests that some renewal is unavoidable.

Looking forward, the topic of monsoons as a whole can be mapped onto the LHAs on “My Climate Risk” and “Explaining and Predicting Earth System Change”. The MP currently links closely with the CLIVAR/Intergovernmental Oceanographic Commission-Global Ocean Observing System (IOC-GOOS) Indian Ocean Regional Panel (IORP). However, it is also necessary to link with other panels e.g., MP's expertise in modeling and data can contribute to ESMOC and MP may have close connections to RifS. The MP is keen to contribute to a greater coordination between panels, including cross-panel workshops.

The WCRP Grand Challenges (GCs) were developed by the WCRP Joint Scientific Committee in 2012 and represented areas of emphasis in scientific research, modeling, analysis and observations for WCRP and its affiliate projects in the decade to follow. GEWEX participates in

three GCs and as all GCs as such will come to an end in 2022, the grand challenge remains how to integrate GC activities and outcomes into GEWEX's Panels.

The GC on *Water for the Food Baskets of the World* focused on assessing how freshwater availability will shift in some of the major food producing regions of the world due to climate change. In April 2012, the Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment ([LIAISE](#)) contributed to this GC by launching a field campaign that brought ground-based and airborne measurements together with modeling studies, including assimilation of remotely sensed data (Fig. 19).

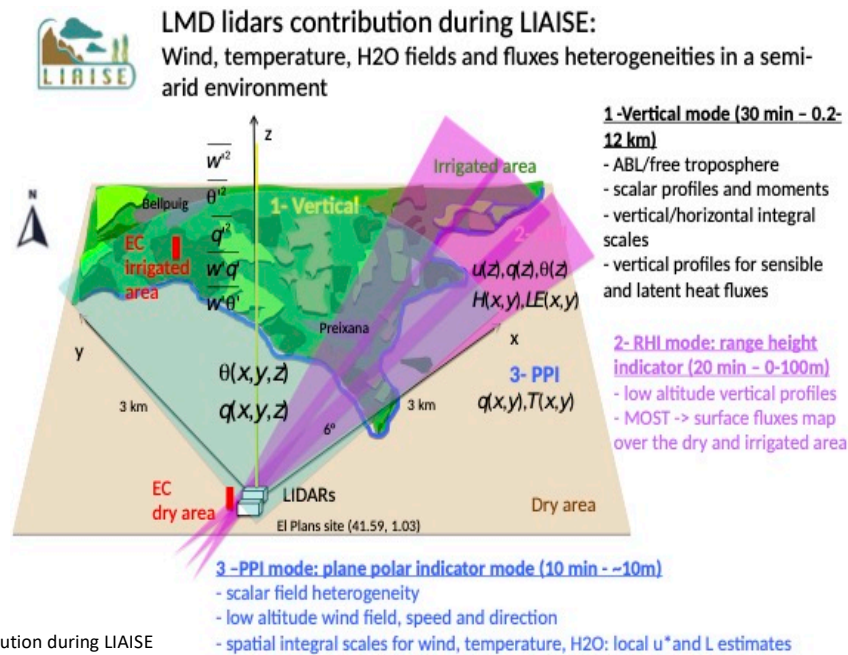


Fig. 19. LMD lidars contribution during LIAISE

Looking ahead, GEWEX has a responsibility to advance the attribution of climate change and human water use as they both modify the continental water cycle. Climate and water management modify extreme events like floods and droughts. The GC *Water for the Food Baskets of the World* is covered in GEWEX by the recently started initiative on Irrigation and interacts with:

- GLASS, to see how the land surface modeling community can be encouraged to add human water use to land surface models
- GHP, to identify critical regions and observe the combined effects of climate change and water use e.g., RHP's HyMeX and GWF and Network PannEx
- GHP CC on Evaporation, to better understand how humans optimize evaporation and its impact on the atmospheric boundary layer.

Other possibilities are looking at the impact of man-made heterogeneities on boundary layer processes (GASS) and/or assessing how far the various observational products represent the natural or actual state of the continental water cycle (GDAP).

The GC on *Clouds, Circulation and Climate Sensitivity* in a nutshell consisted of cross-cutting activities organized around four questions:

1. What controls the position, strength and variability of storm tracks?
2. What controls the position, strength and variability of the tropical rain belts?
3. What role does convective aggregation play in climate?
4. What role does convection play in cloud feedbacks?

Highlights consisted among others of workshops, summer schools, joint publications, the field study *Elucidating the Role of Clouds-Circulation Coupling in Climate* (EUREC⁴A; Fig. 20), two major assessments and several model intercomparison projects.

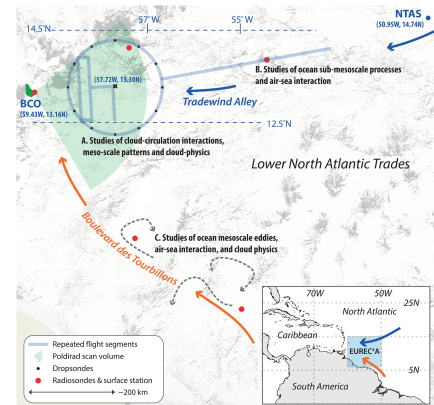


Fig. 20. The EUREC⁴A study area in the lower trades of the North Atlantic

At least two outcomes of this GC can benefit GEWEX science, namely: i) understanding convective organization and its role in climate and ii) shallow convection and clouds. In addition, this GC created great opportunities for GEWEX in terms of possible new Panel activities with strong synergy with other groups e.g., CFMIP/the Working group on Coupled Modelling (WGCM) and WGNE and contributions to WCRP LHAs, especially the LHA “Digital Earths” and the LHA “Explaining and Predicting Earth System Change”.

GC on *Weather and Climate Extremes* is organized around four overarching themes (Document, Understand, Simulate and Attribute) with a main focus on four core events (heavy precipitation, heatwave, droughts and storms) (Fig. 21). Some of the GC *Extremes* success stories are the ongoing collaboration between GDAP and the International Precipitation Working Group (IPWG) leading to the Frequent Rainfall Observations on GridS (FROGS) database, compound events are now widely recognized as part of the research agenda, CMIP is strongly influenced by research needs of extremes and the training of young scientists in the WCRP summer school (2014) and Nanjing fall school (2019). Extremes will continue to be at the heart of GEWEX activities along with climate sensitivity, clouds, feedbacks and rainfall changes, particularly extreme rainfall. At this time discussion is focused on *Extremes* needing a coordination hub, perhaps as part of ESMOC to ensure the widespread focus of extremes has a focal point.

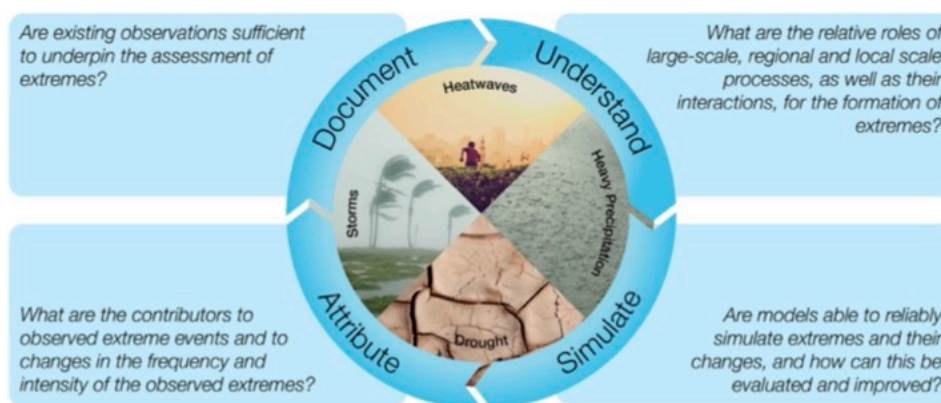


Fig. 21. WCRP Grand Challenge on *Weather and Climate Extremes*

The five WCRP Lighthouse Activities (LHA; Fig. 22), approved at the JSC 41B meeting in 2020, are designed to be ambitious and transdisciplinary (integrating across WCRP and collaborating with partners) in order to 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.



Fig. 22. The five WCRP Lighthouse Activities

The LHA “Safe Landing Climates” is an exploration of the routes to “safe landing” spaces for human and natural systems. It will explore future pathways that avoid dangerous climate change while at the same time contribute to the United Nations Sustainable Development Goals (SDGs). The Lighthouse Activity will focus on five main scientific themes:

1. defining safe landings: defining “safe” (physical climate, impacts, biodiversity), a pathway to it and adaptation/resilience
2. global tail risks (ice sheet collapse, catastrophic large-scale extremes, risk analysis, tipping points)
3. land carbon and bioenergy carbon capture and storage
4. water availability – case studies
5. sea level rise

Potential partners have been contacted and the aim is to have a concrete science plan ready by June 2021.

The goal of the LHA “My Climate Risk” is to develop and mainstream a “bottom-up” approach to regional climate risk that starts from the decision context (and the decision scale) and enables relevant climate information to be brought into that context. By developing a new framework for assessing and explaining the physically plausible climate drivers of regional climate risk, 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, hence flexible and applicable across a number of region types and intended to become a much-needed scientific support for the development of climate services (Labs). The Science Plan Development Team developed an initial Science Plan and the Scientific Steering Group

(SSG) and Ex-Officio membership are currently under development, as are Terms of Reference for regional hubs.

The overarching objective of LHA “Explaining and Predicting Earth System Change” 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, with a focus on multi-annual to decadal timescales. This LHA is organized in three working groups:

1. Observing and Modeling Earth System Change: case studies to understand, constrain, simulate, attribute recent climate anomalies, convergence between climate modeling and earth system data assimilation and reanalysis, uncertainty quantification and observing system design, role of observing systems in causal attribution and innovation in model development
2. Integrated Attribution and Prediction of Earth System Change: provide a process-based understanding of recent multi-annual to decadal climate changes and quantify the roles of internal variability and external drivers including greenhouse gases, aerosols, solar, volcanoes, ozone, land-use and assess predictability, sources of skill and drivers and mechanisms, and hence gain confidence in forecasts
3. Assessment of Current and Future Hazards: understand (explain), quantify and predict weather/climate hazards, focus on specific target phenomena (e.g., heat waves) and understand the natural and anthropogenic drivers of variability and change in classes of weather/climate hazards.

Areas of collaboration with the other LHAs are shown in Fig. 23.

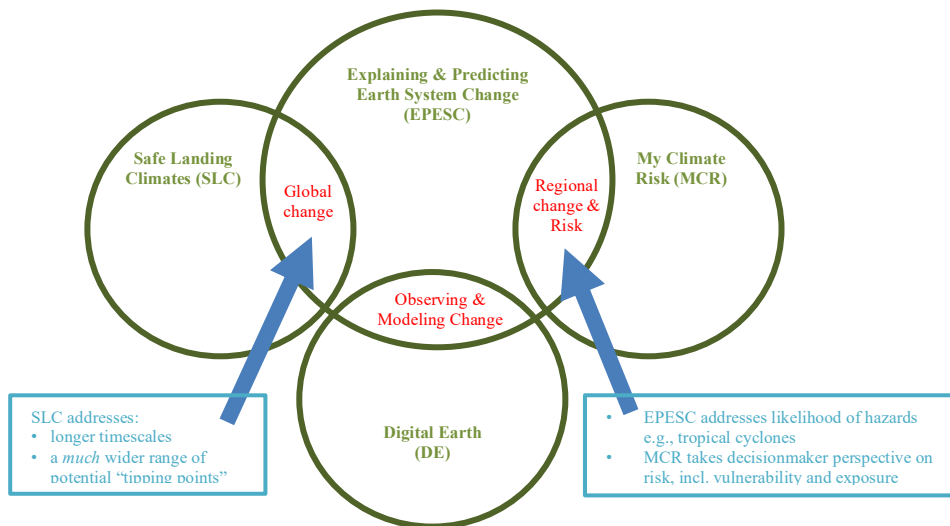


Fig. 23. Areas of collaboration between EPESC and the other WCRP LHAs

The first WCRP workshop on attribution of multi-annual to decadal changes in the climate is organized for September 2021.

The overall objective of LHA “Digital Earths” (DE) is to carry out research activities that support the establishment of integrated interactive digital information systems that provide information on the past, present and future of our planet (Fig. 24). Digital Earths in WCRP should be a framework to develop capabilities across the globe. This requires creating science

activities whose software outcomes are: open and freely available, modular and interoperable, and built to agreed-upon standards. LHA *DE* envisaged both global and regional Digital Twins to be developed under this framework. There are three major areas of activity where WCRP will play a leading role, which are: i) global coupled ultra-high-resolution modeling, ii) data assimilation for climate and iii) Regional Digital Earths systems. These activity areas will be supported by a fourth activity on, "advanced digital technology" that will be well connected to existing expertise on HPC, big data, and AI. There are many opportunities for each GEWEX Panel to contribute in these LHA *DE*'s areas of activity.

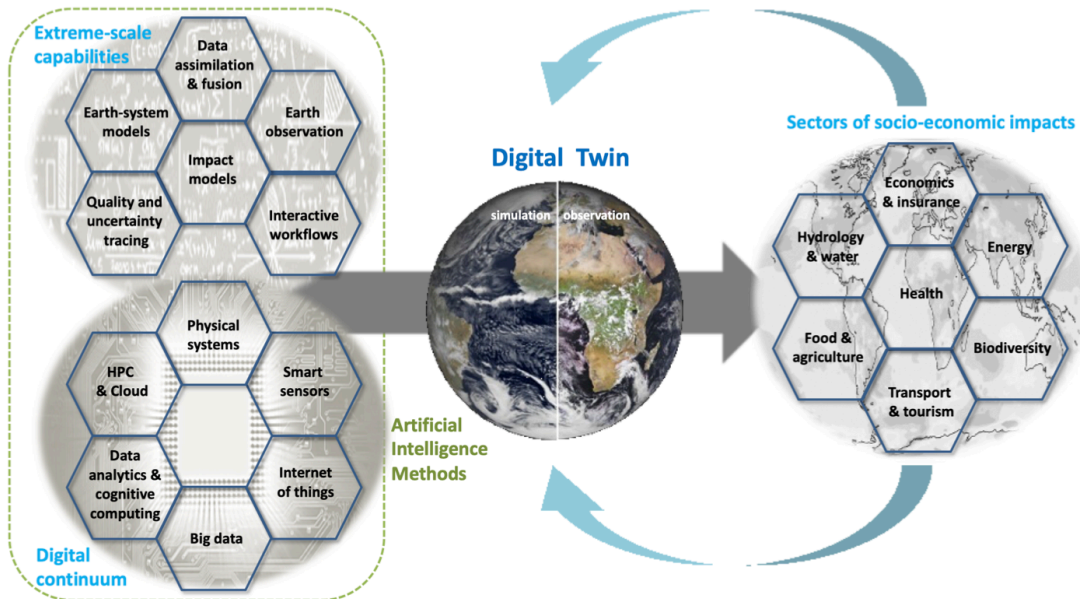


Fig. 24. LHA Digital Earth: A global interactive information system describing past, present and future states of planet Earth.

The LHA “WCRP Academy” is the research training advisory and coordination arm of the World Climate Research Program. Climate expertise is particularly needed in countries most vulnerable to the negative impacts of climate change. Although there is a large amount of excellent climate science training available, coordination of access to this training would benefit those looking for it. The objective of the WCRP Academy is to determine the requirements for climate research education and build enabling mechanisms. One mechanism is an online marketplace for climate science training, which connects training providers and climate scientists who are seeking training. 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. The Academy will also identify training gaps and advocate for those needs to be met.

The WCRP Regional Focal Points (RFP) facilitate the exchange of information between WCRP and the climate research and support communities, stakeholders, and partners in their countries and regions. There are five main WCRP regions:

- Regional Focal Points for Africa
- Regional Focal Points for South America
- Regional Focal Points for North and Central America and the Caribbean
- Regional Focal Points for Asia and Oceania, divided into four subregions groups
- Regional Focal Points for Europe and Western Asia

In this reporting period, each RFP region discussed their role and purpose and focused on organizing the first WCRP climate research forum in the region. The goal of these first fora was to introduce WCRP, including perspectives on the role, benefits and science imperatives of WCRP, collaboration activities in the region and ways to get involved with WCRP.

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 2020
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
Xubin Zeng, 2017 - Outgoing May 2021

Members and Term Dates : Ian Boutle, 2018 - Present
Carla Gulizia, 2020 - Present
Irina Sandu, 2018 - Present
Martin S. Singh, 2019 - Present
Shaocheng Xie, 2018 - Present
Yongkang Xue, 2018 - Present
Ann Fridlind, 2021 - Present

Panel Objectives, Goals and Accomplishments during Reporting Period

Overall Panel Objective(s)

- The Global Atmospheric System Studies (GASS) Panel facilitates and supports the international community that carries out and uses observations, process studies, and numerical model experiments with the goal of developing and improving the representation of the atmosphere in weather and climate models. Primarily, GASS coordinates scientific projects that bring together experts to contribute to the development of atmospheric models.

List of Panel Goals

Adjust yearly

- Sharpen the scientific goals of GASS
- Work with existing project leaders to reach their yearly goals
- Initiate and develop at least one new project
- Continue to explore new ideas for potential GASS projects (e.g., process studies motivated by GC projects; EUREC4A; surface fluxes over ocean, role of convective organization)
- Seek closer collaboration with other GEWEX panels

- Develop the questionnaire to survey climate and NWP modelling centers about their priorities in addressing deficiencies in represented process.
- Close and finalize at least one project (COORDE)

List of Key Results

Adjust yearly with respect to goals

- New panel co-chair (see above)
- Two new panel members (see above)
- Two projects reaching final stage, two others in productive phase. Papers are being published in all projects.
- Planning the pan-GASS conference for October 2021 (now moved to June 2022)
- 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)
- Involvement in defining the WCRP LHA (“Digital Earths” and “Explaining and Predicting Earth System Change”)

Other Science Highlights

Not part of the 2-3 major accomplishments

- COORDE (drag)

At resolutions of 80-100km, most of the models exhibit insufficient or misplaced orographic gravity wave drag in the lower stratosphere with respect to the resolved drag obtained from the km-scale simulations. The total gravity wave drag is also much less at 80km-100km resolutions.

There is a large spread in magnitude and spatial distribution of the parametrized orographic drag across models.

Some of the models exhibit surprising resolution sensitivities in their orographic drag parametrizations
- Demistify (fog)

Representation of cloud droplet sedimentation is essential for NWP fog simulation

Small changes in fundamental parametrizations are more important to fog development than aerosol
- DCP (diurnal cycle of precipitation)

A paper describing the long-term multi-year SCM simulations is being reviewed within co-authors.

Preliminary analysis on CRM/LES and GCM simulations are done and results have been communicated to participating modeling groups.
- LS4P (surface and sub-surface temperature)
 - completion and submission of a paper to Geoscientific Model Development
 - completion of major Phase I model integrations
- UTCC PROES (Upper Tropospheric Clouds and Convection Process Evaluation Study)

- release of 2 data sets (30N-30S, 2012-2016) from TOOCAN convective system tracking approach (<https://toocan.ipsl.fr/>)
- 3D structure of UT cloud systems (30N-30S, 2003-2018) from Machine Learning CIRS data & ERA Interim, trained with 4 CALIPSO-CloudSat data (radiative heating rates from FLXHR)

Panel Activities during Reporting Period

List of Panel Activities and Main Result

- COORDE (drag)
 - The second phase of the COORDE project, looking at 40 km resolutions, was completed at the beginning of 2020.
 - Results were collated and accepted for publication in van Niekerk et al. (2020) JAMES.
- Demistify (fog)
 - 13 participating models submitted results for stage 1
 - Paper on stage 1 results in preparation - 1st draft circulated to co-authors by PI, responses collated, and 2nd draft in progress
- LS4P (surface and sub-surface temperature)
 - A telecon to revise the LS4P regional modeling activity
- DCP (diurnal cycle of precipitation)
 - Complete multi-year SCM simulations over both SGP and Amazon sites
 - Refine the selected case studies based on initial submission
 - The GCM part of the project is still ongoing. Preliminary analysis is done for those models that have submitted their results.
- UTCC PROES (Upper Tropospheric Clouds and Convection Process Evaluation Study)
 - add the mass flux to the UT cloud system data base, via machine learning (3 month visit of Prof. Johnny Luo to LMD (IPSL grant accepted), the visit, initially planned in 2020, had to be postponed to the fall of 2021).

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

- No new projects launched

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

- Discussion have started to initiate new projects in the GASS panel but are too premature to give concrete timelines. The rough idea is, to concretize ideas, to be able to formally launch projects at the pan-GASS conference in June 2022. Also, the role of GASS in the LHA needs to be defined in the coming year.
- There is discussion about follow-up projects in COORDE and Demistify (both projects close to being finalized)

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; DOE ARM is willing to host GASS data. Currently this is tested with data from the Demistify project.
 - The LS4P data bank has also 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
- c. Processes
- GASS projects are about process understanding and model treatment (e.g., precipitation, clouds, surface fluxes, coupling surface to atmosphere, aerosols, dynamics-physics coupling)
- d. Modeling
- GASS projects aim to improve different aspects of atmospheric models and related processes
- e. Application
- GASS projects intends to improve both weather and climate models
- 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 organizes an ERC competition for travel support to the 2022 pan-GASS conference in Monterey.

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

- a. Observations and Predictions of Precipitation
- Three existing GASS projects directly address precipitation: the precipitation diurnal cycle, LS4P, and GAP
- b. Global Water Resource Systems
- One GASS project (LS4P) is directly related to the global water resources systems.
- c. Changes in Extremes
- All GASS projects aim to improve weather and climate models, including their capability in studying weather and climate extremes
- d. Water and Energy Cycles
- All GASS projects aim to improve weather and climate models, including their capability in studying the water and energy cycles. For instance, in the UTCC PROES, upper tropospheric clouds play a crucial role in the climate system by modulating the Earth's energy budget and heat transport. These clouds are most abundant in the tropics, where they often form as cirrus anvils from convective outflow, building mesoscale systems. The radiative heating of the thinner cirrus within the anvils may be critical to cloud climate feedback.

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

- GASS does not have overarching “key science questions” for the next 5-10 years. Three projects list such questions, and they are provided below.
- How realistic are the high-resolution simulations of orographic processes using observations? How can we develop the seamless orographic drag parametrization formulation?
- How does LST/SUBT over global high mountain regions (Including Tibetan Plateau, Rocky Mountains, and other high mountains) affect the global precipitation at S2S scales?

Contributions to WCRP including Current Grand Challenges

Briefly list any specific areas of your panel’s activities in particular to the grand challenges “Extremes” and “Water for the Food Baskets” which is not covered under 2.

- GASS LS4P and precipitation diurnal cycle projects address precipitation that is directly related to “Water for the Food Baskets”
- All GASS projects aim to improve weather and climate models, enabling the modeling study of weather and climate “extremes”
- UTCC PROES contributes to the WCRP Grand Challenge: Clouds, circulation and climate sensitivity.

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

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

- WGNE, SPARC, S2S Prediction Project, CFMIP, and Monsoon panel
- Develop a survey in collaboration with WGNE, GLASS to gather information from NWP and climate modelling centers about deficiencies in process representations to prioritize future projects.

Workshops and Meetings

List of Workshops and Meetings Held in 2020

Meeting title, dates and location

- Continued to have regular videoconferences with panel members
- Improvement and calibration of clouds in models, Toulouse, France, in April 2021. Including a gray-zone II workshop. (Virtual and moved from early in 2020)
- UTCC PROES workshop planned for Sep 2020 in New York had to be canceled due to the pandemic; it was moved to November 2020 in Versailles (just before Earth Observation for Water Cycle Science conference) but had to be canceled again. At that time no virtual meeting is planned.

List of Workshops and Meetings Planned in 2021 and 2022

Meeting title, dates and location and anticipated travel support needs

- The pan-GASS meeting is planned of June 2022
- COORDE workshop held with all collaborators in March 2021

Other Meetings Attended On Behalf of GEWEX or Panel in 2020

- WGNE November 2020, D. Klocke presented GASS activities
- WWRP October 2020, D. Klocke presented GASS activities

Publications during Reporting Period

List of Key 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. Discuss.*, <https://doi.org/10.5194/gmd-2020-329>, in review.
- COncstraining ORographic Drag Effects (COORDE): A Model Comparison of Resolved and Parametrized Orographic Drag, Annelize van Niekerk, Irina Sandu, Ayrton Zadra, Eric Bazile, Takafumi Kanehama, Martin Köhler, Myung-Seo Koo, Hyun-Joo Choi, Yukihiro Kuroki, Michael D. Toy, Simon B. Vosper and Valery Yudin, JAMES
- Tang et al. (including 21 co-authors), 2021: Improving cloud properties through better calibration of parameterizations and subgrid effects increases the fidelity of E3SM Atmospheric Model version 1. To be submitted to QJ.
- Tang et al. 2021: Evaluating the diurnal and semidiurnal cycle of precipitation in CMIP6 models using satellite- and ground-based observations. <https://doi.org/10.1175/JCLI-D-20-0639.1>.
- Xie et al. 2020: Improving the simulation of Diurnal precipitation over Monsoon regimes. *GEWEX Quarterly*, Vol. 30, No. 4, Quarter 4, 2020.
- Fiolleau, T., R. Roca, S. Cloché, D. Bouniol, P. Raberanto, Homogenization of geostationary infrared imager channels for cold cloud studies using MeghaTropiques/ScaRaB. *IEEE Trans. Geosci. Remote Sens.*;DOI: 10.1109/TGRS.2020.2978171 (2020)
- 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)

2.2 GEWEX Data and Analysis Panel (GDAP)

Full Panel Name (Acronym)	: GEWEX Data and Analysis Panel (GDAP)
Reporting Period	: 01 January–31 December 2019
Starting Date	: 2018
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) Wouter Dorigo (2013–2020) Andrew Heidinger (2011 - Present) Seiji Kato (2017–Present) Chris Kummerow (2014–2020) Hirohiko Masunaga (2010–Present) Isable Trigo (2017–Present)

GDAP stands for GEWEX Data Analysis Panel, and we have engaged in emphasizing the analysis part and it is slowly building up. We have promoted the consistency theme as a way to channel the undergoing various new activities.

GDAP is sponsoring some surface networks, organizing and publishing community-based assessments of various water and energy fluxes and encouraging and managing some data-related projects. We summarize below the recent achievements of these three activities and sum up the other efforts undertaken at the panel level to better connect with the other panels and the SSG.

GDAP networks

This is the more formal and historical activity we are dealing with in the panel. Indeed, we have no say about the directions or the evolution of the networks and just make sure the networks data and effort are connected to the satellite world. The GPCC precipitation network is reporting to us and is well used in many of the assessment chapters. The ISMN deals with soil moisture and is going under change of leadership. A better connection to the US network into the global picture is under discussion. Note that here Peter is involved, probably more than GDAP. The BSRN network thrives thanks to its dynamical leadership, reinforced this year with a deputy chair. Tristan L’Ecuyer participates actively in the BSRN science meetings. While not officially in our portfolio, we include the ARM facility management into GDAP as well in the same spirit as for BSRN. There are ongoing discussions about including these networks better with GDAP and are developing ideas for a cross-panel emerging surface budget project centered on these networks (see below).

GDAP assessments

This is the more community-oriented activity since under each assessment group there is a large gathering of worldwide scientists involved in the actual assessment effort. Note that the terminology “assessment” is vague and may represent many things. In our case, the report it is often a review of the literature with added specifically design benchmarks and intercomparison exercise. The reporting can take the form of a BAMS article and/or a 200 pages WCRP report. TLE and RR have renewed the exercise when we took over and make it community-centric and broad following the example of the Cloud assessment.

Clouds (C. Stubenrauch)

While the cloud assessment is officially finished and published, the community asked Claudia Stubenrauch to run a subset of the diagnostics on the latest version of the cloud product. This little extension is undergoing and progressed substantially this past year offering a perspective on the progress of the various satellite cloud groups.

GVAP-2(M. Schröder et al.)

This is the second phase of the water vapor assessment that follow a successful first phase and a hefty report of more than 200 pages. The GEWEX Water Vapour Assessment (G-VAP, <http://gewex-vap.org>) quantifies the state-of-the-art in water vapor products being constructed for climate applications. G-VAP considers total column water vapor, profiles and humidity in the upper/free troposphere, with a focus on satellite data records and stability. Interim results on an assessment of water vapor products in the Arctic was published in AMTD (Crewell et al., 2020). Among others it was concluded that for monthly mean values, systematic differences are present in the Arctic which particularly appear over different surface types, e.g. ocean and sea ice. The full-blown report is due in 2021.

Precipitation (R. Roca and Z. Haddad)

The initial precipitation assessment has been scaled up by making it jointly with IPWG (a WMO/CGMS body dedicated to precipitation) and is now in press after 3 years of co-writing with 19 contributors. The report enjoys 9 chapters entertaining from the high-resolution precipitation product capability to the research directions for uncertainties modelling. There is a dedicated chapter on precipitation extreme that benefited from a cooperation between GDAP and GC Extreme, between R. Roca and L. Alexander that yield to a workshop and a special issue with ~15 papers. A side product of this cooperation is the FROGS database that ease the access to more than 30 precipitation products. Beyond satellite products, FROGS includes ground based data sets as well as reanalysis. It is worth noting that we have incorporated the GLASS sponsored centennial reanalysis into FROGS following the last SSG discussion. Also note a specific chapter by the GDAP crew where the consistency between the various global products and the global radiation budget is explored revealing large discrepancies among the precipitation products and the lack of consistency. The overall recommendation from the precipitation community towards the space and operational agencies are currently being worked out.

Earth Energy Imbalance (B. Meyssignac and T. Boyer)

There is a growing focus in the energy balance community to understand where the excess heat in the climate system resulting from increased concentrations of greenhouse gases actually goes. Globally, the annual mean net energy absorbed by the Earth is referred to as Earth Energy Imbalance (EEI). It is a fundamental variable defining the status of global climate change but very challenging to estimate from observations. A range of EEI estimates have been published in the last decade, often with error bars that are difficult to robustly trace to measurement principles. Within the consistency paradigm, GDAP has recently initiated an assessment of the current available EEI estimates from observations. Since the ocean stores more than 90% of the total planetary heat uptake, the EEI assessment focuses on intercomparing estimates of the time rate of change of ocean heat content (ocean heat uptake). The results of this first of its kind EEI assessment focus on: (a) understanding the spread of global and regional ocean heat content and ocean heating rate among products, (b) determining systematic errors that depend on assumptions, models, and combined observations, and (c) understanding the spread of uncertainties depending on the method and formulae used. A second phase of the EEI project may further seek to assess estimates of ocean heat uptake on regional scales and determine error covariance matrices that depend on region and ocean depth.

GDAP projects

The ISCCP-NG project

While slowed by the pandemic due to the lack of in-person meetings, GDAP continues to coordinate a community effort to develop a next generation International Satellite Cloud Climatology Project (ISCCP-NG). The goals of this ISCCP-NG effort are to (a) maintain continuity of the ISCCP while (b) developing new global cloud products that exploit the increased spatial and temporal resolution, spectral diversity, and improved calibration afforded by advanced geostationary imagers to support new research and applications. This is viewed by many of the major satellite and weather agencies around the globe as a critical step to maximizing the benefits of the advanced observing systems of today and tomorrow but requires considerable effort to engage this broad community and ensure this is a truly *International* effort. Through a series of workshops, GDAP is currently facilitating the gathering of international community input to maximize the benefits of the ISCCP-NG product for meeting user needs. Current efforts have centered on generating a set of intercalibrated radiances from the constellation of modern geostationary satellites (termed L1g) that will form the basis for a series of associated atmospheric parameter products. It is anticipated that a geostationary cloud assessment ISCCP-NG effort will be required to move the project forward to producing cloud products and GDAP will play a key role in coordinating that effort.

The Integrated Product project

The IP project was the longest lasting project in GDAP, starting in 2010 or before. It was very ambitious and was supposed to provide an integrated product. For various complicated and valid reasons that have been articulated in a GEWEX newsletter article by Chris Kummerow, it was failing and about to be stopped as a GDAP sponsored project late 2019 when a less ambitious solution was promoted. We now have all the fluxes and the ISCCP clouds on the same grid same resolution and same period. Yet the surface sensible and latent flux over land are not homogeneous over the period and include both satellite retrievals and ERA-5 data. The aerosols and cloud products that were supposed to be included in all the fluxes computations (aka integrated) ended up being used with various versions and not as integrated as planned. Yet this is an important data set that can help the community investigating science questions. This effort is now sunsetting since there is no financial nor strong scientific support to improve the existing

20 years record called the IP product; yet the actual individual products are likely to be extended in time as is.

Regional Energy and Water Cycle Consistency over Land project (new)

As an outgrowth of the IP project, a workshop focusing on using the IP to study regional energy and water cycle closure over land was initially planned for Toledo, Spain in spring 2020. Due to two postponements because of the pandemic, this workshop is being repurposed to develop the foci of a cross-panel GDAP-GLASS activity centering on land-atmosphere heat and moisture exchanges. The project will fill a long-desired need to better engage local field sites like ARM and BSRN (as well as 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 study will be built around establishing consistency between land-atmosphere heat and water exchanges and observed surface temperature and water storage changes on local scales using field observations and local process modeling. Insights gleaned from these scales will be expanded to regional and ultimately global scales using satellite energy and water cycle data sets and global models (including reanalyses). One possible deliverable from this activity is an assessment of land energy and water cycle fluxes but that requires additional discussion. A workshop is planned, likely in early 2022 to bring together relevant members of both panels and others in related communities to produce a white paper outlining the project goals and plan for achieving them.

GEWEX-centric activities

Contribution to the SSG discussion

We have contributed to the high email traffic about the positioning of GDAP and GEWEX with respect to the space agencies in the first quarter of 2021. We have produced and communicated notes for people to access some of the reasoning behind the positioning of GDAP. We understand we have contributed to improve the communication in the SSG by providing the much-needed background of the GDAP activity for interested folks.

Liaison with GLASS

In support of developing a cross-panel project with GLASS and fostering increased interaction between the panels in general, a formal GDAP-GLASS liaison has been appointed. Dr. Yunyan Zhang from LLNL has been appointed as a member of both panels and will serve in this role in the coming years to increase communication between the panels.

Emerging discussion with GAS

The simultaneous maturity of GAS and incorporation into GEWEX of the momentum of the GC on Clouds and Circulation is a good trigger for further interactions between GDAP and GAS. Sandrine Bony and Rémy Roca have planned to discuss these possible connections in the coming months.

Update of the web site

While it may look trivial, it actually is a time-consuming task that has been performed mainly by Tristan this year. The GDAP webpages are now reflecting well the panel activity.

WCRP-centric activities

WCRP ESMOC

RR is representing GEWEX in the ESMOC discussion. First meeting planned on May 3rd.

Light house etc..

We have had little if no time to actually articulate GDAP activity into the reorganization of the WCRP. Please also note that GDAP is not directly involved in any of the WCRP working groups and this is a topic of concern since the GEWEX representatives are belongs to the other panels.

2.3 GEWEX Hydroclimatology Panel (GHP)

Full Panel Name (Acronym) : GEWEX Hydroclimatology Panel (GHP)
Reporting Period : 01 January - 31 December 2020
Starting Date :
End Date (where appropriate) : NA
URL : <https://www.gewex.org/panels/gewex-hydroclimatology-panel/>

Membership

Chair(s) and Term Dates : Joan Cuxart, 2017 - 2020
 Francina Dominguez, 2018 - Present
 Ali Nazemi, 2020 - Present
Members and Term Dates : Paola Arias, 2019 - Present
 Craig Ferguson, 2015 - 2020
 Li Jia, 2019 - Present
 Xin Li, 2016 - Present
 Andreas Prein, 2019 - Present
 Joshua Roundy, 2020 - Present
 Vidya Samadi, 2019 - 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 to from an integrated perspective.

List of Panel Goals

Adjust yearly

- The GEWEX Hydroclimatology Panel (GHP) aims at providing an improved understanding of environmental water and energy exchanges to from 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 projects, to achieve the mentioned tasks: (1) Regional Hydroclimatological Projects (RHPs) that are tools 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 and 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, providing continuity to ending actions in GEWEX as well as welcoming activities that have a regional aspect and are not currently structured as a RHP.

List of Key Results

Adjust yearly with respect to goals

- COVID-19 brought in-person meetings to an abrupt halt and impacted the progress of existing and prospective GHP projects. However, the 2020 GHP meeting, marking the first fully virtual GHP meeting, showed that GHP activities have been adapting to the new reality and making progress despite limitations as a result of Covid-19 pandemic.
- Significant and continued progress by Global Water Futures (GWF) and Baltic Earth, the two mature ongoing RHPs with a large group of active researchers and established ties with local communities. After 10 years, HyMeX has come to an end but a new generation of researchers will likely begin a new chapter. The LIAISE campaign serves as an effective link between the old and the new HyMeX initiatives.
- We are enthusiastic about the four prospective RHPs that are quite advanced and almost ready to launch: the Asian Precipitation Experiments (AsiaPEX), the Third Pole Environment-Water Sustainability (TPE-WS), the Regional Hydrology Program for the Andes (ANDEX) and the United States RHP (US-RHP). It is expected that Science Plans for these initiating RHPs will be reviewed by the panel in 2021.
- Currently, there are two ongoing CCs: The International Network for Alpine Catchment Hydrology (INARCH), which begins its second phase. The new CC, Transport and Exchange Processes in the Atmosphere over Mountains Experiment (TEAMx), is progressing very well, with tremendous opportunity for knowledge sharing with INARCH as well as ongoing and prospective RHPs such as ANDEX, TPE-WS and GWF. The 2020 GHP meeting marked an end to a very successful CC, INTELLigent use of climate models for adaptation to non-Stationary hydrological Extremes (INTENSE). There is also a community shaping around a prospective CC, i.e. Determining Evapotranspiration (ET CC). The ET CC had its second workshop in February 2021.
- The Global Precipitation Climatology Centre (GPCC) and the Global Runoff Data Centre (GRDC) Data Centers are both making steady and significant progress. In particular, the new data portal from GRDC has increased data requests dramatically. The International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE) has limited activities and connections outside of Russia.
- PannEx, an initiating RHP, aiming at providing a better understanding of Earth system processes over the Pannonian Basin, has decided to become at this point a GHP Network. Networks provide a more flexible way to continue interactions compared to a RHP.

Other Science Highlights

Not part of the 2-3 major accomplishments

- After seven years in the GHP Panel and four years of leadership, Joan Cuxart stepped down as co-chair of GHP. Ali Nazemi was appointed as the new co-chair of GHP.
- After six years of dedicated service to GHP, Craig Ferguson stepped down as GLASS-GHP liaison and was replaced by Josh Roundy.
- Ali Nazemi and Paola Arias are representing GHP in the World Climate Research Program's Lighthouse Activities. Ali Nazemi also represents GHP in Interim Coordinating Committee (ICG) of the new WCRP Home Regional Information for Society (RifS).

Panel Activities during Reporting Period

List of Panel Activities and Main Result

Current RHPs:

- Baltic Earth continues to progress steadily. Two of the main activities are the BEAR (Baltic Earth Assessment Reports) and EN Clime. BEAR are a series of extensive assessment reports, while EN Clime is a concise "Baltic Sea climate change fact sheet". Both of these are very large collaborative and interdisciplinary undertakings. There is also sustained research by the core group of investigators, key scientific results from modeling studies highlight the importance of using coupled atmosphere-ocean models as opposed to uncoupled scenarios such as Euro-CORDEX because the feedbacks, particularly during the warm season, are strong. The group also published several studies regarding European climate variability and the teleconnection influence of NAO, AMO.
- Global Water Futures GWF is at the mid-point of its 7-year program and has made many important scientific advances including the co-creation of research with Indigenous Communities, generation of 'big data' for water, significant advancements in modelling and prediction systems, including national-scale flood and drought forecasting for Canada and knowledge mobilization and engagement with users and practitioners across Canada and globally.
- After 10 years, HyMeX comes to an end. An overview paper will be prepared to highlight its most important achievements and contributions. A strong group of young researchers will lead a "new phase" of HyMeX, enlarging it to southern and Eastern countries and new communities. The new scientific approach will be based on transversality and multidisciplinary and will consider social impacts and needs. The LIAISE campaign is scheduled for the summer of 2021 with a focus on semi-arid surface processes and human influence on the water cycle. This activity can serve as a link between the previous and new era of HyMex.

Current CC:

- INARCH is a very active CC aimed at better understanding of alpine cold regions hydrological processes, improve their prediction, diagnose their sensitivities to global change, and find consistent measurement strategies. With 28 research basins in 13 countries, INARCH will build links with US Water for Foodbaskets, Canada's GWF, ANDEX and TPE. One of the highlights is an ESSD special issue "Hydrometeorological data from mountain and alpine research catchments". INARCH is at the end of its initial 5-year term. The activities and objectives for the second phase of the program are currently in planning.
- The 2020 GHP meeting marked an end to INTElligent use of climate models for adaptation to non-Stationary hydrological Extremes (INTENSE), a very successful INTENSE CC.

Current Data Centers:

- The Global Precipitation Climatology Centre (GPCC) continues steady and significant progress. GPCC is well connected to the other GHP and GEWEX activities.
- The Global Runoff Data Centre (GRDC) focuses on acquisition harmonization, and storage of global historical river discharge data. The center is progressing very well and new data are continuously added into the system. The new GRDC data portal has significantly increased the requests for data.
- The International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE) seems to be moving slowly as it is less connected to GHP activities and/or other global efforts. Part of the issue is that this effort depends strongly on Valery Vuglinsky, who has not been very active in Baltic Earth lately.

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

New CC:

- TEAMx is a new CC that has been very active. The plan for the TEAMx Observational Campaign has been prepared by the Field Observations Committee and this involved collating existing measurements infrastructure, contacting PIs and network operators, identifying potential observational facilities and defining target areas. The TEAMx White Paper was published; a webinar was held in May 2020; and two committees have been established.

New Networks:

- PannEx, was an initiating RHP focused on a better understanding of Earth system processes over the Pannonian Basin. However it was decided that PannEx becomes a GHP Network rather than a RHP. Networks provide a more flexible way to continue the interactions of an RHP. For PannEx, this will allow developing a more widely-involved community, delaying its application to become a full, active RHP to a later stage.

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

Prospective RHPs:

- Asian Precipitation Experiments (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. Also, a new BAMS article is underway. AsiaPEX will submit to become a GEWEX RHP this year.
- ANDEX has been very active in the development and publication of a series of articles in Frontiers that lays the groundwork on the current knowledge on the Hydroclimate of the Andes. This is the backbone of their White Book, which should be open for comments by April 2021. ANDEX will have an implementation plan and submit to become a GEWEX RHP in the summer of 2021.
- Third Pole Environment-Water Sustainability (TPE-WS) has very strong research teams in addition to large and well-funded infrastructure. 17 PBL towers have been installed with several microwave radiometers. 18 high-quality papers have been published. There have also been lake field campaigns in the region. During the meeting it was appeared that there is a need for better communication between TPE and GHP to identify common goals.
- 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 GHP encouraged the team to put together a Science and Implementation plan following their current ideas to apply for initiating status in 2021.

Prospective CC:

- Determining ET is a prospective CC activity to analyze ET-related issues in a coordinated way, avoiding dispersion of actions and crossing disciplinary borders. A workshop was organized in the GEWEX Hydroclimate Panel in Sydney in October 2019 with 34 attendees. The second workshop was held in February 2021 to put together the science plan. The GHP notes strong links between the ET CC and the LIAISE effort.

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 data sets and generate new ones as their activities progress, either with new campaigns or with the expansion of their networks. HyMeX will continue to provide data sets through the LIAISE field campaign and the next generation of HyMeX researchers.
- CCs also produce new data sets. As INTENSE now finalized, the data collection is now completed and their database on sub-daily precipitation and complementary numerical model data are archived and provided to GPCC. INARCH continues to compile data from the 26 basins that form the network. TEAMx has submitted two proposals to strengthen instrumental facilities.
- GRDC has enhanced their data portal, which has increased their data availability.
- The PannEx network has published daily Penman-Monteith reference evapotranspiration values based on CarpatClim data set.
https://www.met.hu/en/omsz/palyazatok_projektek/carpatclim/

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. The analysis of this comprehensive information often leads to new insights.

c. Processes

- Each GHP activity focusses on some particular aspects. Regionally-focused RHPs are broad efforts. The main focus of Baltic Earth is to provide a better understanding of Baltic Sea region as a complex biogeochemical case study. GWF is more oriented to changing climate, land, water and ecosystems water in cold regions. HyMeX's new LIAISE effort focuses on processes in semi-arid regions with large human influences. CCs described above tackle specific processes in a transregional setting. INARCH focuses on better understanding of hydrological processes in alpine cold regions, while TEAMx is a nice complement because it focuses on atmospheric transport and exchange processes over mountains. These two efforts together can provide a set of comprehensive finding regarding atmospheric, cryospheric and hydrologic processes that affect freshwater availability within and downstream of mountainous regions.

d. Modeling

- Due to the diversity in research questions, purposes and processes within different GHP activities, a variety 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 variety 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 data sets, modeling methodologies and assessment frameworks that can serve the society through improved regional Meteorological and Hydrological Services.
- f. Technology Transfer
- Datasets, model parameterization, bench markings 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 re-analyses, 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 Questions and plans to include these.

- a. Observations and Predictions of Precipitation
- Provided by GWF, Baltic Earth, HyMeX, INARCH, INTENSE, GPCC.
- b. Global Water Resource Systems
- INARCH, GWF and HyMeX (LIAISE) have a well-defined hydrological component, also covered by the GRDC data center on Runoff. PannEx has planned to work intensively on the water management at the basin scale and provided Penman-Monteith reference evapotranspiration values based on CarpatClim data set.
- c. Changes in Extremes
- The study of the occurrence and trends of extremes in the present climate is made by all GHP activities. The INTENSE CC was particularly focused on this aspect. The future changes are usually studied through regional climate modelling, either specific studies/activities or through coordinated actions, such as in CORDEX
- d. Water and Energy Cycles
- Most RHPs do not devote an equivalent effort to all parts of the energy and water cycles. Concerning the water cycle, precipitation is well addressed in general, while only some RHPs analyze the hydrological part, and evapotranspiration is not a subject of organized research to the date. This is a well-detected limitation and will be tackled by the ET CC when it comes to fruition. The LIAISE activity will also help in this aspect.

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" 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 Current Grand Challenges

Briefly list any specific areas of your panel's activities in particular to the grand challenges "Extremes" and "Water for the Food Baskets" which is not covered under 2.

- Most GHP activities contribute to the "weather and climate extremes" grand challenge by generating data, field campaigns and modelling efforts. The three prospective RHPs will have a significant component related to weather and climate extremes.
- "Melting ice and global consequences" is an important subject for Baltic Earth, GWF and INARCH and it will be for ANDEX and TPE-WS after they turn to active RHPs.
- "Regional sea level change and coastal impacts" is a main theme for Baltic Earth in general and is a point of focus for HyMeX related to severe weather impacts.
- "Water for the food baskets of the world" is an issue that is considered in ongoing activities, e.g. GWF, and is being considered in new actions, such as PannEx network and the LIAISE field campaign. This is also in the exploratory phase like ANDEX or the US RHP.
- "Carbon feedbacks in the climate system" is explored in Baltic Earth, that has a strong biogeochemical component. The prospective ET CC has also strong carbon component related to transpiration.
- "Near-term climate prediction" is considered, but normally handled within other actions such as CORDEX.
- "Clouds, circulation and climate sensitivity" are taken care of in modelling studies within RHPs.
- It is important to highlight the Ali Nazemi and Paola Arias are currently involved in the WCRP Lighthouse Activity related to "My Climate Risk". Ali Nazemi also represents GHP in Interim Coordinating Committee (ICG) of the new WCRP Home Regional Information for Society (RifS).

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). We have a new GLASS representative, Josh Roundy, who will enhance collaborations.
- 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 new 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.

- 2020 GHP "Virtual Meeting" due to COVID-19

List of Workshops and Meetings Planned in 2021 and 2022

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

- 2021 GHP meeting. Likely Virtual due to COVID-19

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.

Publications during Reporting Period

List of Key Publications

- See individual Working Group 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 2020
Starting Date : NA
End Date (where appropriate) : NA
URL : <https://www.gewex.org/panels/global-landatmosphere-system-study-panel/>

Membership

Chair(s) and Term Dates : Mike Ek, 2015 - 2020 (member 2009 - Present)
 Kirsten Findell, 2019 - Present (member 2018 - Present)
 Anne Verhoef, 2020 - Present (member 2017 - 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
 ^Craig Ferguson, 2011 - Present
 Samiro Khodayar Pardo, 2019 - Present
 *Hyungjun Kim, 2010 - Present
 *David Lawrence, 2014 - Present
 Joshua Roundy, 2016 - Present
 *Joseph Santanello, 2011 - Present
 Volker Wulfmeyer, 2020 - Present
 Yijian Zeng, 2020 - Present
 ^Eleanor Blyth, 2011 - 2020
 Martyn Clark, 2017 - 2020
 Chiel van Heerwaarden, 2012 - 2020
 Sujay Kumar, 2015 - 2020
 Aude Lemonsu, 2017 - 2020
 ^Pere Quintana Seguí, 2017 - 2020
 Kun Yang, 2017 - 2020
 * *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 a protocol for evaluating experiments to address the central question, "Does my land model describe the processes in the climate system sufficiently well?"
- To develop an optimal system to create global land data sets in which information is extracted from both land models and sophisticated observations.
- To estimate the contribution of memory in the land system to the overall predictability of regional atmospheric phenomena at seasonal time scales.

List of Panel Goals

Adjust yearly

- Promote the importance and development of improved observations of the L-A system, namely in the PBL, as well as improved utilization of soil moisture and surface fluxes measurements in models. (LoCo and GLAFO)
- Develop and operate GLAFOs from groundwater to soil to land cover to the lower troposphere.
- Develop and promote internationally accepted benchmarks for land model performance (ILAMB).
- Develop the capability to use features such as (i) standard reference tests, (ii) benchmarking capability and (iii) a simple to use workflow environment related to both of the above as part of a continuous integration pipeline for land model development, allowing automated science testing (PALS)
- Quantify the potential improvement of LSMs given existing observational constraints, using empirical models and information theory based approaches (PLUMBER2)
- Identify which aspects of process representation are causing poorer than expected LSM performance, and how they might be improved (PLUMBER2)
- Extend the empirical benchmarking methodology to benefit other related research areas (PLUMBER2)
- Surveying and comparing the hydraulic pedotransfer functions (PTFs) that are used in global climate models. In relation to this conducting various sensitivity analyses of the effect of these different functions on the water and energy balance (SoilWat)
- Analysing a soil parameter MIP (SP-MIP), conducted globally with 8 key land surface models (SoilWat)
- Surveying and comparing the thermal pedotransfer functions and key equations that are used in global climate models, and their effect on the water and energy balance (SoilWat)
- Developing a new generation of pedotransfer functions that integrate vegetation as a surrogate for soil structure; revisiting old parameter estimation from PTFs by adding new physical constraints (SoilWat)
- Expanding estimates of global surface evaporation considering soil properties and associated resistances (SoilWat)

- Surveying how groundwater is implemented in climate models and the development of strategies for better incorporation of groundwater in climate models (SoilWat).

List of Key Results

Adjust yearly with respect to goals

- LoCo paradigm is at the forefront of multiple activities funded by NOAA, NASA, and DOE. Multiple field campaigns include a strong LoCo-driven component.
- Set up and test of GLAFO synergy at the Land-Atmosphere Feedback Observatory (LAFO) of the University of Hohenheim (see <https://lafo.uni-hohenheim.de/en>).
- Assessment of CMIP6 coupled models compared to CMIP5 models shows general and broad improvement in land-related fields captured by ILAMB. Assessment being used within IPCC AR6 report. (<https://www.ilamb.org/CMIP5v6/historical/>)
- Significant upgrades to ILAMB interface and usability.
- LUMIP land-use harmonization version 2 paper describing historical and future land use and land management scenarios paper published (Hurtt et al., 2020; doi.org/10.5194/gmd-13-5425-2020)
- PALS hosted the PLUMBER MIP, which for the first time enabled standardised benchmarking of LSMs across the LSM community.
- PALS has been relaunched as modevaluation.org with a much more flexible structure that is no longer specific to LSMs.
- Successful incorporation of ILAMB as analysis package within modevaluation.org
- PLUMBER(2) showed that LSMs can perform much better than they currently do, given the amount of information they are provided with in meteorological forcing data.
- PLUMBER(2) showed that LSMs were consistently outperformed by linear regressions against downward shortwave when predicting sensible heat flux
- Successful use of Machine Learning to derive improved hydraulic conductivity data sets globally (SoilWat)
- Delivery of tangible recommendations to LS modelers on the performance and pitfalls of widely used PTFs (SoilWat)
- Solid guidance on how to improve root architecture and hydraulics in LSMs (SoilWat)

Other Science Highlights

Not part of the 2-3 major accomplishments

- New approaches to measure atmospheric surface layer profiles using a synergy of scanning remote sensing in combination with tower measurements and new methods for the evaluation of these observations using similarity-theory and machine-learning approaches to improve the parameterization of surface fluxes (GLAFO).
- Most PLUMBER2 contributions are submitted (20+), still chasing a few
- Urban PLUMBER well underway, beginning phase 2
- PLUMBER2 showed that poor LSM performance was due to partitioning issues, rather than the calculation of the amount of available energy
- Using different PTFs in hydrological models causes substantial variability in predicted fluxes. It is recommended to harmonize the PTFs used in model inter-comparison studies, to distinguish model diversities caused by the choice of PTFs from those induced by different model physics/structures.

Panel Activities during Reporting Period

List of Panel Activities and Main Result

- Preparation of a GLAFO summary document for distribution to interested parties. GLAFO White Paper and Implementation Plan in preparation.
- Processing, QC and hosting full suite of FLUXNET2015, La Thuile and OzFlux site data, optimised for LSM evaluation using FluxnetLSM R package (Ukkola et al, 2017) - 170 sites made the cut - hosted on modevaluation.org (PALS)
- Significant effort to include meta-data for each flux tower site - reference heights, vegetation heights and type, additional site information, including photos - in site profile on modevaluation.org (PALS)
- A discussion paper of the importance of groundwater in global hydrological/climate models ("Global groundwater modeling and monitoring: Opportunities and challenges"; Condon et al., 2021). Inputs from Stefan Kollet and Anne Verhoef from SoilWat and others in GEWEX, ISMC and wider communities. A revised paper is currently in the process of being re-submitted to Water Resources Research (SoilWat)
- A comparison paper on the soil thermal properties in Land surface models. Re-runs and new runs with Hydrus based on the configurations used in Weihermüller et al. (2021) will be used to steer this paper in a new direction (SoilWat)
- Analysis of a soil parameter MIP based on global runs with 8 key land surface models, led by Lukas Gudmundsson and Matthias Cuntz. Model groups submitted results, data tidying will be overseen by various members of the Land Surface Processes group of the University of Reading (SoilWat)
- A data paper on existing globally distributed data sets of soil thermal properties, led by Hailong He, in progress (SoilWat)

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

- Paper describing the QC / conservation / meta data process for these 170 sites to follow (PALS)
- PLUMBER2 submissions need to be finalized and analysis needs to begin
- Most PLUMBER2 empirical models finalized (regressions, cluster+regressions, LSTMs)
- Determination of global thermal properties from soil texture and mineralogy data. Such a data set would enhance the current model capabilities of land surface/climate models in the context of prediction of soil heat flux and soil temperature profiles, which should improve model predictions of the energy-, water- and carbon balance (SoilWat).
- New generation PTFs using vegetation attributes to inject soil structure into soil hydraulic properties (Lead Lutz Weihermüller and Yonggeng Zhang, ISMC) (SoilWat)

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

- Discussions underway with Martin Best (UKMO), and interest from ECMWF, to develop modevaluation.org as part of science-based extension to continuous integration in land model development (i.e. automated science testing with repository check in). Leads would be Gab Abramowitz, Martin Best and Martin DeKauwe. Timeline uncertain, but should be clearer next year (PALS)

- Development of soil-process evaluation metrics for MIPs that might make the importance of (improved) soil processes more 'visible' to ESM/LSM communities. This will include developing global observational data sets (as reference data needed for MIPs), establishing relevant performance metrics (statistical, as well as soil physically meaningful metrics), and communicating with groups like ILAMB/PLUMBER to include these metrics in their routine evaluations (leads: Yijian Zeng, Anne Verhoef). First steps will be a brief 'white paper' and online workshop with key GLASS and ISMC members (SoilWat)
- The scenario simulation outcomes from the sensitivity study of the effect of PTF on the water balance will be revisited to check the potential effect of PTF choices on the thermal regime (SoilWat)
- Establishing a survey of existing soil models in land surface models (as embedded in ESMs). This will be building upon the ISMC Early Career Research Workshop held in Nov. 2019 (lead: Yijian Zeng, SoilWat)

Science Issues and Collaboration during Reporting Period

Contributions to Developing GEWEX Science and the GEWEX Imperatives.

a. Data Sets

- GLAFO measurements available from observatory at the Univ. of Hohenheim.
- LUMIP land use harmonization version 2
- Extensively quality controlled, gap-filled flux tower data set (170 sites) in ALMA / CF-netcdf has been prepared (used for PLUMBER2), available on modevaluation.org, paper being written
- (CoGTF) <https://doi.org/10.5281/zenodo.3934853> (SoilWat)
- (SoilKsatDB) <https://zenodo.org/record/4541586#.YFu7c2hKhaQ> (SoilWat)
- (Dai et al's Soil Hydraulic & Thermal Properties) <http://globalchange.bnu.edu.cn/research> (SoilWat)
- (Multiyear ELBARAIII TB data) https://figshare.com/articles/dataset/Update_Multiyear_in_situ_L-band_microwave_radiometry_of_land_surface_processes_on_the_Tibetan_Plateau/12728444/1 (SoilWat)

b. Analysis

- LoCo Cheat Sheets: http://cola.gmu.edu/dirmeyer/Coupling_metrics.html
- Scrutiny of Pedotransfer functions for water and energy balance predictions (SoilWat)

c. Processes

- LoCo Cheat Sheets: http://cola.gmu.edu/dirmeyer/Coupling_metrics.html
- GLAFOs cover processes from radiation to surface fluxes to turbulent transport and beyond
- Infiltration, surface evaporation, soil water and heat transfer, soil-root hydraulics, transpiration, soil-groundwater interactions (SoilWat)

d. Modeling

- LoCo Cheat Sheets: http://cola.gmu.edu/dirmeyer/Coupling_metrics.html
- LUMIP: Land use change modeling, including assessment of expanding sets of represented land management processes
- We are trying to develop modevaluation.org to provide a science-based extension to continuous integration in land model development (i.e. automated science testing with repository check in). If successful this would be available for public use

- HYDRUS1D as a common platform to explore impact of PTF choices on soil water/heat transport. Plans to compare with SWAP model, to have another reference (SoilWat)
 - The coupling between STEMMUS (soil model) and SCOPE/T&C (vegetation/carbon model) was implemented for understanding impact of soil water/heat transfer on land surface water-energy-carbon fluxes (SoilWat)
 - A new surface evaporation capacitor (SEC) model - dynamic near surface domain representation, has been extended to include the competing effects of drainage in an analytical framework (SoilWat)
- e. Application
-
- f. Technology Transfer
- Commercialization and operational application of new remote sensing systems at GLAFO observatories.
 - As noted above, we are trying to develop modevaluation.org to provide a science-based extension to continuous integration in land model development (i.e., automated science testing with repository check-in). If successful, this would be available for public use
 - Soil process knowledge transfer from soil to land surface community (SoilWat)
- g. Capacity Building
- As noted above, we are trying to develop modevaluation.org to provide a science-based extension to continuous integration in land model development (i.e., automated science testing with repository check-in). If successful, this would be available for public use
 - Improving the capability of our current land surface and climate models via improved soil modelling (SoilWat)

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

- a. Observations and Predictions of Precipitation
- Ferguson's group showed potential predictability of Great Plains low-level jets and associated precipitation at 1-month lead times linked to circumglobal teleconnection (see LoCo report publications).
 - Many papers on SM-P coupling (see LoCo Report publications).
 - More accurate characterization of pre-convective conditions with respect to dynamics and thermodynamics for better understanding and simulation of clouds and precipitation (GLAFO).
 - Data assimilation of GLAFO observations for advanced forecasting of cloud and precipitation development.
- b. Global Water Resource Systems
- Tricia Lawston-Paker is resurrecting the GEWEX irrigation discussion and potential initiative, and has convened two meetings with Jan Polcher, Peter van Oevelen and the GHP and GLASS co-chairs to brainstorm on ideas for the best way forward given the scope of GHP/GLASS expertise, interests, and tools (i.e. models). There will likely be leveraging of the LIAISE MIPs and data sets related to irrigation and water use.

- Precise description of soil processes will help to improve the prediction of global water resources systems, for example, in terms of soil-root hydraulics, soil water/heat coupled transfer, soil-groundwater interactions (SoilWat)
- c. Changes in Extremes
- Changes in extremes are reliant upon L-A interactions and feedbacks that determine the connection of soil moisture to precipitation. As such, new projects from Roundy (NASA SMAP), Dirmeyer (SMAP, MAP), and Ferguson (MAP) will address these feedbacks using LoCo metrics, models, and data sets
 - Ultimately, SoilWat will improve predictions of land surface states and fluxes, which will subsequently improve the predictions of 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
- d. Water and Energy Cycles
- Changes in extremes are reliant upon L-A interactions and feedbacks that determine the connection of soil moisture to precipitation. As such, new projects from Roundy (NASA SMAP), Dirmeyer (SMAP, MAP), and Ferguson (MAP) will address these feedbacks using LoCo metrics, models, and data sets
- SoilWat is evaluating how PTF/Soil Properties will impact the water and energy balance

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? (SoilWat)
- What are the roles of soil-root-plant hydraulics and soil-groundwater interactions in affecting land-atmosphere interactions? (SoilWat)

Contributions to WCRP including Current Grand Challenges

Briefly list any specific areas of your panel's activities in particular to the grand challenges "Extremes" and "Water for the Food Baskets" which is not covered under 2.

- SoilWat will potentially contribute to the evaluation/assessment of crop/agriculture water productivity, as such contributing to 'Water for the Food Baskets'
- SoilWat can help to provide more accurate land surface states/fluxes that will help improve prediction of 'Extremes'

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

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

- 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 2020

Meeting title, dates and location

- GLASS Panel Meeting (virtual), November 23-25, 2020
- SoilWat break-out meeting at EGU (April 2020, Online)
- SoilWat break-out meeting for 'Thermal Property WG' (October 2020, Online)

List of Workshops and Meetings Planned in 2021 and 2022

Meeting title, dates and location and anticipated travel support needs

- SoilWat break-out meeting at EGU, AGU and possibly at the ISMC biannual assembly (online)
- ISMC-SoilWat Thermal Working group meeting on 8 June 2021.
- SoilWat Workshop on the development of evaluation metrics for soil processes in climate models (planned for June 2021)

Other Meetings Attended On Behalf of GEWEX or Panel in 2020

- Anne Verhoef: The GEWEX Cross-cut 'Evaporation' meeting (online, February 2021), organised by Oscar Hartogensis and colleagues in Wageningen

Publications during Reporting Period

List of Key Publications

- Wulfmeyer et al., 2020: The GEWEX Land-Atmosphere Feedback Observatory (GLAFO). GEWEX Newsletter GEWEX Quarterly, 30(1), 6-11.
- Hurtt, G.C., L. Chini, R. Sahajpal, S. Frolking, B.L. Bodirsky, K. Calvin, J.C. Doelman, J. Fisk, S. Fujimori, K.K. Goldewijk, T. Hasegawa, P. Havlik, A. Henimann, F. Humpnoder, J. Jungclaus, J. Kaplan, J. Kennedy, T. Kristzin, D. Lawrence, P. Lawrence, L. Ma, O. Mertz, J. Pongratz, A. Popp, B. Poulter, K. Riahi, E. Shevliakova, E. Stehfest, P. Thornton, F.N. Tubiello, D.P. Van Vuuren, and X. Zhang, 2020. Harmonization of Global Land-Use Change and Management for the Period 850-2100 (LUH2) for CMIP6. GMD, 13, 5425-5464, doi.org/10.5194/gmd-13-5425-2020.
- Gupta, S., Hengl, T., Lehmann, P., Bonetti, S. & Or, D. SoilKsatDB: global soil saturated hydraulic conductivity measurements for geoscience applications. Earth Syst. Sci. Data Discuss. 2020, 1–26 (2020)
- Dai, Y. et al. A Global High-Resolution Data Set of Soil Hydraulic and Thermal Properties for Land Surface Modeling. J. Adv. Model. Earth Syst. 11, 2996–3023 (2019)
- Weihermüller, L. et al. Choice of Pedotransfer Functions matters when simulating soil water balance fluxes. J. Adv. Model. Earth Syst. e2020MS002404 doi:10.1029/2020MS002404
- Dai, Y. et al. A review of the global soil property maps for Earth system models. SOIL 5, 137–158 (2019)
- Zhao, H., Zeng, Y., Lv, S. & Su, Z. Analysis of soil hydraulic and thermal properties for land surface modeling over the Tibetan Plateau. Earth Syst. Sci. Data 10, (2018).
- Dai, Y. et al. Evaluation of Soil Thermal Conductivity Schemes for Use in Land Surface Modeling. J. Adv. Model. Earth Syst. 11, 3454–3473 (2019).
- Vereecken, H. et al. Infiltration from the Pedon to Global Grid Scales: An Overview and Outlook for Land Surface Modeling. Vadose Zo. J. 18, 1–53 (2019).
- Or, D. & Lehmann, P. Surface Evaporative Capacitance: How Soil Type and Rainfall Characteristics Affect Global-Scale Surface Evaporation. Water Resour. Res. 55, 519–539 (2019).
- Lehmann, P., Merlin, O., Gentine, P. & Or, D. Soil Texture Effects on Surface Resistance to Bare-Soil Evaporation. Geophys. Res. Lett. 45, 10,398-10,405 (2018)
- Lehmann, P., Berli, M., Koonce, J. E. & Or, D. Surface Evaporation in Arid Regions: Insights From Lysimeter Decadal Record and Global Application of a Surface Evaporation Capacitor (SEC) Model. Geophys. Res. Lett. 46, 9648–9657 (2019)

- Vanderborght, J. et al. From hydraulic root architecture models to macroscopic representations of root hydraulics in soil water flow and land surface models. *Hydrol. Earth Syst. Sci. Discuss.* 1–37 (2021) doi:10.5194/hess-2021-14.
- Condon, L.E., Kollet, S., Bierkens, M.F.P., Fogg, G.E., Maxwell, R.M., Hill, M.C., Verhoef, A., Van Loon, A.F., Sulis, M., Hendricks Franssen, H.J.; Abesser, C. Global groundwater modeling and monitoring: Opportunities and challenges. *Water Resour. Res.* (under revision)
- Bonetti, S., Wei, Z. & Or, D. Blueprint for quantifying hydrologic effects of soil structure across scales (under revision). *Comm. Earth Environ.*

Annex 1: List of Participant

GEWEX SCIENTIFIC STEERING GROUP

Jan Polcher, Co-Chair

Laboratoire de Météorologie Dynamique du CNRS
Paris, France
Email: jan.polcher@lmd.jussieu.fr

Graeme Stephens, Co-Chair

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

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

Paul Dirmeyer

George Mason University
Fairfax, VA, USA
Email: pdirmeye@gmu.edu

Qingyun Duan

Beijing Normal University
Beijing, China
Email: qyduan@bnu.edu.cn

Gabi Hegerl

University of Edinburgh
Edinburgh, Scotland
Email: gabi.hegerl@ed.ac.uk

Christian Jakob

Monash University
Clayton (VIC), Australia

Email: christian.jakob@monash.edu

B.J. Sohn

Seoul National University
School of Earth and Environmental Sciences
Seoul, Korea
Email: sohn@snu.ac.kr

Bob Su

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

GEWEX PANEL REPRESENTATIVES

Sandrine Bony

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

Daniel Klocke

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

Francina Dominguez

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

Tristan L'Ecuyer

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

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

Xubin Zeng

GASS Co-chair
University of Arizona
Tucson, AZ, USA
Email: xubin@email.arizona.edu

WCRP REPRESENTATIVES**Lisa Alexander**

Joint Scientific Committee, GEWEX
Liaison
University of New South Wales
Sydney, Australia
Email: l.alexander@unsw.edu.au

Helen Cleugh

Vice-Chair Joint Scientific Committee
World Climate Research Programme
Commonwealth Scientific and Industrial
Research Organisation (CSIRO)
Canberra, ACT, Australia
Email: Helen@HACleugh.com

Jim Hurrell

Joint Scientific Committee, GEWEX
Liaison
Colorado State University
Fort Collins (CO), U.S.A.
Email: jhurrell@rams.colostate.edu

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

Tere Cavazos

RFP North & Central America,
the Caribbean and Greenland
Centro de Investigación Científica y de
Educación Superior de Ensenada (CICESE)
Ensenada, B.C., México
Email: tcavazos@cicese.mx

Andrew Charlton-Perez

LHA WCRP Academy
University of Reading
Reading, United Kingdom
Email: a.j.charlton-perez@reading.ac.uk

Johannes Cullmann

WMO Hydrology and Cryosphere
Geneva, Switzerland
Email: jcullmann@wmo.int

Boris Dewitte
RFP South America
Centro de Estudios Avanzados en Zonas
Aridas (CEAZA)
La Serena, Chile
Email: boris.dewitte@ceaza.cl

Michael Ek
The National Center for Atmospheric
Research (NCAR)
Boulder, CO, USA
Email: ek@ucar.edu

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

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

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

Oscar Hartogensis
Wageningen University & Research
Wageningen, The Netherlands
Email: oscar.hartogensis@wur.nl

Bruce Hewitson
WCRP Regional information for Society
CSAG/University of Cape Town
Cape Town (Rondebosch), South Africa
Email: hewitson@csag.uct.ac.za

Jin Huang

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

Renu Joseph
U.S. Department of Energy
Washington DC, U.S.A.
Email: Renu.Joseph@science.doe.gov

Tadahiro Hyasaka
Japan Aerospace Exploration Agency
(JAXA)
Tsukuba-Ibaraki, Japan
Email: tadahiro.hayasaka.b4@tohoku.ac.jp

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

Rupa Kumar Kolli
CLIVAR/GEWEX Monsoon Project Office
Pune, Maharashtra, India
Email: r.kolli@clivar.org

Irène Lake
CORDEX International Project Office
Stockholm, Sweden
Email: irene.lake@smhi.se

Sonya Legg
Co-Chair CLIVAR
Geophysical Fluid Dynamics Laboratory
Princeton, NJ, USA
Email: slegg@princeton.edu

Chris Lennard
RFP Africa, Middle East
CSAG/University of Cape Town
Cape Town (Rondebosch), South Africa
Email: lennard@csag.uct.ac.za

L. Ruby Leung

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

Sally McFarlane
U.S. Department of Energy
Washington DC, U.S.A.
Email: sally.mcfarlane@science.doe.gov

Philippe Maisongrande
Centre National D'Études Spatiales (CNES)
Toulouse, France
Email: MaisongrandeP@cnes.fr

Hal Maring
National Aeronautics and Space
Administration (NASA)
Washington, DC, USA
Email: hal.maring@nasa.gov

Dominic Matte
RFP North & Central America,
the Caribbean and Greenland
Niels Bohr Institute
Copenhagen, Denmark
Email: dominic.matte@nbi.ku.dk

Anil Mishra
United Nations Educational, Scientific and
Cultural Organisation (UNESCO)
Paris, France
Email: a.mishra@unesco.org

Aurel Moise
CLIVAR/GEWEX Monsoon Panel
Centre for Climate Research Singapore
Singapore, Singapore
Email: aurel.moise@bom.gov.au

Riko Oki
Japan Aerospace Exploration Agency
(JAXA)
Tsukuba–Ibaraki, Japan
Email: oki.riko@jaxa.jp

Regina R. Rodrigues

LHA My Climate Risk
Universidade Federal De Santa Catarina
Florianópolis, SC, Brazil
Email: regina.rodrigues@ufsc.br

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

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

Jörg Schulz
Exploitation of Meteorological Satellites
(EUMETSAT)
Darmstads, Germany
Email: joerg.schulz@eumetsat.int

Catherine Senior
Earth System Modelling and Observational
Capabilities (ESMOC)
Metoffice UK
Exeter, Devon, United Kingdom
Email: cath.senior@metoffice.gov.uk

Ted Shepherd
LHA My Climate Risk
University of Reading
Reading, United Kingdom
Email: theodore.shepherd@reading.ac.uk

Lars Smedsrud
CliC
University of Bergen,
Bergen, Norway
Email: Lars.Smedsrud@uib.no

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

Drew Story



U.S. Global Change Research Program
(USGCRP)
Washington DC, USA
Email: dstory@usgcrp.gov

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: GEWEX SSG-33 Agenda

Monday 3-May

<i>Los Angeles</i> 05:30 - 09:40	<i>New York</i> 08:30 - 12:40	<i>Paris</i> 14:30 - 18:40	<i>Delhi</i> 18:00 - 22:10	<i>Beijing</i> 20:30 - 00:40	<i>Sydney</i> 22:30 - 02:40		Start	End
GEWEX Data and Analysis Panel (GDAP)				Rémy Roca, Tristan L'Ecuyer			0:00	0:50
Short Break							0:50	1:00
Global Land/Atmosphere System Study (GLASS) Panel				Kirsten Findel, Anne Verhoef			1:00	1:50
Short Break							1:50	2:00
GEWEX Hydroclimatology Panel (GHP)				Francina Dominguez, Ali Nazemi			2:00	2:50
Short Break							2:50	3:00
Global Atmospheric System Studies (GASS) Panel				Xubin Zeng, Daniel Klocke			3:00	3:50
CLIVAR/GEWEX Monsoon Panel				Aurel Moise, Leila Carvalho			3:50	4:10

Tuesday 4-May

<i>Los Angeles</i> 05:30 - 08:45	<i>New York</i> 08:30 - 11:45	<i>Paris</i> 14:30 - 17:45	<i>Delhi</i> 18:00 - 21:15	<i>Beijing</i> 20:30 - 23:45	<i>Sydney</i> 22:30 - 01:45		Start	End
WCRP's New Structure for the Future				Jim Hurrell			0:00	0:15
LHA ¹ Explaining and Predicting Earth System Change				Kirsten Findel Rowan Sutton			0:15	0:30
LHA ¹ My Climate Risk				Ted Shepherd			0:30	0:45
LHA ¹ Safe Landing Climates				Gabi Hegerl			0:45	1:00
LHA ¹ Digital Earths				Christian Jakob			1:00	1:15
LHA ¹ WCRP Academy				Andrew Charlton-Perez Angela Maharaj			1:15	1:30
Break							1:30	1:40
<u>Regional Focal Point (RFP) - groups Round Table</u>								
RFP Africa, Middle East				Chris Lennard				
RFP South America				Boris Dewitte and Carla Gulizia				
RFP North & Central America, The Caribbean and Greenland				Tereza Cavazos and Dominic Matte			1:40	2:30
RFP Eastern Asia				Hyungjun Kim				
RFP Oceania				Lisa Alexander				
RFP Southeast Asia				Fredolin Tangang				
RFP Southern Asia				TBD				
RFP Europe, Russia, Middle East and Iceland				TBD				
Break							2:30	2:45
WCRP's Earth System Modelling and Observational Capabilities (ESMOC) Core Project				Cath Senior			2:45	3:00
WCRP Regional information for Society (RiS)				Daniela Jacob			3:00	3:15

¹ LHA: Light House Activity

Wednesday 5-May

<i>Los Angeles</i> 05:30 - 09:30	<i>New York</i> 08:30 - 12:30	<i>Paris</i> 14:30 - 18:30	<i>Delhi</i> 18:00 - 22:00	<i>Beijing</i> 20:30 - 00:30	<i>Sydney</i> 22:30 - 02:30		Start	End
<u>Agency Roundtable</u>								
National Centre for Space Studies (CNES) : Philippe Maisongrande								
Copernicus / European Centre for Medium-Range Weather Forecasts (ECMWF) : Carlo Buontempo								
European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) : Jörg Schulz								
European Space Agency (ESA) : Diego Fernandez						0:00	2:00	
Japan Aerospace Exploration Agency (JAXA) : Tadahiro Hayasaka								
National Oceanic and Atmospheric Administration (NOAA) : Jin Huang								
National Aeronautics and Space Administration (NASA) : Jared Entin								
U.S. Department of Energy (DOE) : Renu Joseph								
Intergovernmental Hydrological Programme (IHP) UNESCO : Anil Mishra								
Pacific Northwest National Laboratory (PNNL) : Ruby Leung								
Break							2:00	2:15
GC Extremes						Gabi Hegerl	2:15	2:25
SPARC						Seok-Woo Son	2:25	2:35
GC Water for Food Baskets						Jan Polcher	2:35	2:45
CLIVAR						Sonya Legg	2:45	3:00
CLIC						Lars Smedsrud	3:00	3:15
GC Clouds						Sandrine Bony	3:15	3:30
CORDEX						Irène Lake	3:30	3:45

Thursday 6-May

<i>Los Angeles</i> 05:30 - 09:00	<i>New York</i> 08:30 - 12:00	<i>Paris</i> 14:30 - 18:00	<i>Delhi</i> 18:00 - 21:30	<i>Beijing</i> 20:30 - 00:00	<i>Sydney</i> 22:30 - 02:00		Start	End
WCRP JSC						Helen Cleugh Detlef Stammer	0:00	0:30
WMO - Res Department / WCRP Secretariat / WMO – Hydrology and Cryosphere						Mike Sparrow Johannes Cullmann	0:30	1:00
Discussion						Jan Polcher	1:00	1:15
Break							1:15	1:30
WCRP Regional information for Society (RifS)						Bruce Hewitson	1:30	2:00
SATM						Graeme Stepherns Jan Polcher	2:00	2:15
30 Years Paper						Graeme Stephens	2:15	2:30
GEWEX Cross Cuts Evaporation						Oscar Hartogensis	2:30	3:00
New Initiatives and Strategy						Xubin Zeng	3:00	3:30
Next Meeting Date and Location / AOB						Peter van Oevelen	3:30	3:45

Annex 3: Rapporteur Reports on GEWEX Panels

Rapporteurs report for the 33rd GEWEX SSG Meeting

Panel: Global Atmospheric System Studies (GASS)

Rapporteur(s): Gianpaolo Balsamo and Mike Bosilovich

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

The GASS panel report provides an overview of the activities conducted in the panel. The co-chairs made special efforts to ensure that the GASS panel is well aligned with GEWEX objectives via its projects (DCP, COORDE, Demistify, LS4P, UTCC PROES).

Achievement of annual goals for this reporting period

All projects are active with ongoing publications. Noticeable involvement in the new WCRP Lighthouses (“Digital Earths” and “Explaining and Predicting Earth System Change”).

Major accomplishments and results in reporting period

Major advances in the understanding of drag impact (collaboration with WGNE) thanks to COORDE. LS4P and DCP completed the first phase. Demistify reached large model participation in stage one. Innovative use of machine learning in UTCC PROES.

Arisen or noted science issues

Needs for novel science projects to replace the finished ones (discussions and plans already ongoing in GASS panel) and connect with new high-resolution modelling initiatives (eg. DTE).

Emerging Science

Flow in complex orographic/coastal areas, as linked with breeze flow and diurnal cycle or large scale (eg. monsoon) flow. A Stratospheric Sudden Warming focus. Ocean fluxes in highly variables surface temperature areas. Convective organisation.

Future plans

Pan-GASS meeting in 2022 to refocus community interest. Greater use of observations for process understanding using models as supporting tool (eg. flux partitioning).

Recommendations to Panel

Consider enlarging the panel with process experts. Effort in 2020 to add new members noted.

Considerations for SSG

Suggest focus areas to map into Light-Houses Activities. Consider new projects to replace finished ones. Suggest virtual meeting to maintain projects' engagement.

Additional Remarks

Remarkable efforts to continue and accomplish the panel activities and produce timely the reports, in challenging times.

Rapporteurs report for the 33rd GEWEX SSG Meeting

Panel: GEWEX Data and Analysis Panel (GDAP)

Rapporteur(s): P. Dirmeyer and Chr. Jakob

Adherence to GEWEX and Panel's objective(s)

The Panel's work adheres perfectly to the Project and Panel objectives.

Achievement of annual goals for this reporting period

See GDAP report

Major accomplishments and results in reporting period

See GDAP report

Arisen or noted science issues

ISSCP-NG level-1 pilot data set produced – needs extension to ~1 year. Resource limitations have been noted as an issue. There is a great opportunity to connect this work to the evaluation and assessment of the emerging new generation of global km-scale models. For this to work, coordination of the year chosen for the pilot study with the modelling groups would be extremely helpful!

Emerging Science

See recommendations below.

Future plans

Regional Energy and Water Cycle Consistency over Land project (cross w/ GLASS) – very promising – an opportunity for progress beyond what the Integrated Product (IP) was able to accomplish.

Recommendations to Panel

WCRP's "Earth System Modelling and Observational Capabilities" (ESMOC) as the replacement for WDAC and WMAC is still to be scoped - terms of reference, structure, governance, etc. but also research priorities and a forward work plan are to be determined. So, there is still ample opportunity to get engaged and share GDAP activities and plans. We think this is an opportunity to engage positively and shape ESMOC so that it integrates with GDAP activities.

Earth Energy Imbalance (EEI): GCOS also has an energy imbalance initiative – need to coordinate there. Also, EEI seems ready- made to engage other WCRP elements beyond GEWEX. Link to processes would be an important second step, as it brings the scientific understanding. Links to reanalyses should also be considered. As reanalyses are still conducted without climate applications in mind (i.e., violations of closure in state variables), the results are likely not so great, but highlighting this would be timely. One of the goals of the Digital Earths Lighthouse is to use next-generation data assimilation to fully describe the state of the system including past states. Success in this would mean that we can estimate EEI from those systems. To measure this success, we need to know what the truth is (the current EEI assessment will likely provide estimates of that) but also what the starting point looks like (current re-analysis).

Take the opportunity of the new project on **regional consistency over land** to bring in global observationally based monitoring efforts on missing budget elements, e.g., satellite soil moisture (SMAP, ESA-CCI, etc.) and surface heat fluxes (e.g., FLUXCOM from MPI-Jena, etc.), and potentially with GHP efforts that already have regional foci. And may consider an ocean version like the new “consistency over land” effort.

Evaporation being the link between energy and water at the surface (ocean + land) some interaction with the Evaporation CC in GHP would be helpful to identify if all processes driving evaporation are represented in the various estimates.

Considerations for SSG

Leadership in place for 5 years now – plans to refresh?

Additional Remarks

IP project: There appears to have been no overlap between Landflux surface sensible and latent heat flux, which will make it very hard to use this for anything. Could we use some other/older data sets (e.g., GSWP) to fill in this hole?

Rapporteurs report for the 33rd GEWEX SSG Meeting 2021

Panel: GEWEX Hydroclimatology Panel (GHP)

Rapporteur(s): Z. Su, G. Poveda, G. Hegerl

Adherence to GEWEX and Panel's 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 from an integrated perspective.' This is very well adhered to.

Achievement of annual goals for this reporting period

GHP aims at providing an improved understanding of environmental water and energy exchanges from 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 that affect natural to socio-economic aspects of freshwater availability and demand. GHP includes an impressive list of projects of four types to achieve the annual goals. From the 2020 virtual GHP meeting and the report, the panel is congratulated for achieving the stated annual goals.

Major accomplishments and results in reporting period

The 2020 virtual GHP meeting reported the GHP activities and progresses despite limitations imposed by the Covid-19 pandemic.

The details of the accomplishments and results can be found in the panel report and are discussed with the assigned SSG members.

Arisen or noted science issues

A few technical issues were raised, and suggestions made to strengthen the executions of some activities (see recommendations). We noted again that the International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE) had not reported on its activities.

Emerging Science

The community is shaping around a prospective Cross-Cutting Project, Determining Evapotranspiration (ET CC), which organized its second workshop in February 2021, and attracted strong interest and support from the research community worldwide.

The representation of GEWEX/GHP by Ali Nazemi (GHP co-chair) and Paola Arias in the World Climate Research Program's Lighthouse Activities is considered to be very important.

Future plans

The future plans appear very comprehensive and include many project-specific activities.

Recommendations to Panel

The SSG members would like to congratulate the GHP panel for effectively coordinating the many projects and for achieving the annual goals. For specific projects we have made the following recommendations and discussed the follow-ups with the GHP co-chairs in an on-line meeting.

- To improve the performance of the International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE), we have proposed to engage Jean-François Crétaux. GEWEX International Project Office (IGPO) has contacted CNES/ESA for a follow-up meeting. We propose to further discuss this issue with the CNES representative at the upcoming SSG-33.
- We have proposed to contact Yaoming Ma to set up a meeting to clarify expectations regarding TPE for a potential path forward to become an RHP. Li Jia and Xin Li should be part of this meeting as both GHP panel members have close links to TPE.
- We have proposed to consider a TPE-link with PannEx. IGPO has sent out an invitation to relevant parties for further discussions. GHP panel will coordinate with PannEx once more information is available.
- In addition, to emphasize on droughts within GEWEX' realm of actions, despite having shorter timer scales, floods should be viewed on equal footing due to their very large impact on society and how they are projected to change in a future climate. It was also suggested that a Cross-Cutting project (CC) on floods is a natural "successor" to the INTENSE CC by Ali Nazemi.
- As a CC on floods and droughts it might be beneficial to invite Justin Sheffield (Uni. Southampton and part of the non-profit Princeton Climate Institute) as suggested by IGPO.

Considerations for SSG

The participations in the 2020 virtual GHP meeting and the workshop on Determining Evapotranspiration (ET CC) in February 2021 have been very informative and beneficial to gain more understanding of the natures of the various activities. It is suggested that respective SSG members should try to participate in future events of GEWEX Panels.

Additional Remarks

The GHP co-chairs are congratulated and thanked for their effective coordination of the multitude of GHP activities.

Rapporteurs report for the 33rd GEWEX SSG Meeting 2021

Panel: Global Land/Atmosphere System Study (GLASS)

Rapporteur(s): Qingyun Duan and B.J. Sohn

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

GLASS' main objectives are: (1) to improve understanding of energy and water cycling on land and in the coupled land-atmosphere system; and (2) to improve representation of these processes in earth system models. The GLASS Panel has nine ongoing projects, with one close to completion. Those projects can be classified into process-oriented projects (e.g., LoCo, DICE/GABLS, GLAFO, and SoilWat), benchmarking projects (e.g., PLUMBER2, PALS and ILAMB) and model intercomparison projects (e.g., GSWP3 and LS3MIP).

The GLASS projects are highly relevant to GEWEX' mission and imperatives, address some of the key GEWEX science questions and are important components of GEWEX Process Evaluation Studies (PROES). Particularly the process-oriented projects address the GEWEX science questions related to water and energy cycles and associated processes. The benchmarking projects serve an important role in enhancing land surface models by introducing community accepted benchmarks and evaluation metrics. The model intercomparison projects work towards quantifying model improvement based on current understanding of model deficiencies and identifying gaps in representing land- atmosphere interaction and water/energy cycles.

Achievement of annual goals for this reporting period

Annual goals set from last year have been achieved mostly despite the impact of COVID-19 pandemic.

Major accomplishments and results in reporting period

Major accomplishments are in areas of:

- observations of Land-Atmosphere system (e.g., LoCo, GLAFO), especially Planetary Boundary Layer (PBL) and from ground to soil to lower troposphere;
- development of community accessible model evaluation and intercomparison platforms and interfaces (e.g., modevaluation.org, standard reference tests, a simple to use workflow and automated scientific testing);
- leading a number of international model intercomparison projects (MIPS) and playing a major role in contributing to CMIP6 (LUMIP, PLUMBER MIP);
- solid progress in SoilWat in bringing groundwater process in land surface models.

Arisen or noted science issues

- How do we resolve the discrepancies in MIPS? A number of MIPS revealed tremendous discrepancies in model results. It seems that not much effort has been made in the past to resolve the discrepancies.
- How should we consider streamflow (runoff) in water cycle in GLASS projects (it's an old issue)? Streamflow records are one of best pieces of information on water budget closure. Current GLASS projects don't seem to take advantage of this information.
- How do we account for the effect of urbanization on land surface processes and land-atmosphere interactions? Current projects seem too much focus on the vegetation area.

- Similar emphasis may be put on the land processes over the permafrost area such as Siberia, where the potential greenhouse gas emission is immense.

Emerging Science

How do we consider water and energy cycles under the changing climate, especially in terms of climatic extremes?

Future plans

Emerging initiatives:

- Irrigation in land surface models: Initial conversations underway, led by Tricia Lawston-Parker (LoCo WG) and involving Jan Polcher, Anne Verhoef, Kirsten Findell, Peter van Oevelen.
- GLASS-GDAP collaborations: With the arrival of Yunyan Zhang as the new GLASS-GDAP liaison, conversations are underway about a number of possible initiatives, beginning with the utility of the GDAP integrated product for GLASS objectives.

Recommendations to Panel

- Remove DICE/GABLS from the list of GLASS projects. This project hasn't been active for years. We can add it back to the portfolio if the effort is rekindled.
- Remove LUMIP from the list of GLASS projects. Project Lead Dave Lawrence indicated that though analyses will continue in the coming months, the project was driven by CMIP6 timelines and has largely been concluded.

Considerations for SSG

By BJ Sohn

- Clear signposting of impacts of GLASS efforts on (research on and solutions to) societally important topics such as extremes (heat waves, floods, droughts) and climate change. Recent studies indicate that the prolonged soil moisture deficit in dry arid regions can further shift already shifted probability distributions of global warming induced summer temperatures.
- Recognize that soil moisture has been identified as a key factor exacerbating heatwaves and severe droughts through the land-atmosphere coupling, adding more attentions on the climate extremes to the current GLASS activities can further augment the scientific and societal benefits.
- Dedicate effort to improve understanding and predictions of interactions between urban land surfaces and the atmosphere. The urban area has been known to be a major greenhouse gas source area (about 70% of the total emission). In particular, methane, which has a much profound impact on the greenhouse effect, is considered to be an important climate change mitigation target over the relatively shorter period (this is an ongoing effort worldwide).
- See the importance of the interactions between the land surface and the atmosphere influencing the carbon cycle, added new panel member and associated activities are recommended.
- Close collaborations with the other GEWEX panels (e.g., GDAP) to create a coherent set of heat (latent and sensible) fluxes for land surface, ocean and land-ice (observations, model outputs or a mix). Global pictures of such flux parameters will give a reference to the climate science communities, in the area of model validation and diagnostic studies such as heat transport and surface energy balance variation.

By Yun Duan

GLASS projects should pay attention to an old issue raised in the past about putting more emphasis on runoff and streamflow. Both are key components of the water cycle and one of the best observed variables. This would entail getting more hydrologists involved in GLASS projects, rather than just atmospheric scientists projects. The SoilWat project is a good opportunity to bring atmospheric scientists and hydrologists together. In addition, the variability and availability of water is intimately connected to societal impacts. To address these issues we need the perspectives from hydrologists.

Another old issue is to really address the model discrepancies seen in MIPS, as is evidenced in PLUMBER and iLAMB outputs. We need to know what causes these discrepancies and how to resolve them.

Additional Remarks

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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
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	COncstraining 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)
ESMOC	Earth-System Modelling and Observation Capability
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
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
GHP	GEWEX Hydroclimatology Panel
GHRSSST	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
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
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
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
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
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
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 1 Geo-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
LIAISE	Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment
LIS	Land Information System (NASA)
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 Environnementale 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
OAFflux	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
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
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
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 segmentationN

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
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	Working Group on Seasonal to Interannual Prediction
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.*

