2022 GDAP Annual Meeting and ISSI Global Water-Energy Cycle Challenges Workshop

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The 2022 GEWEX Data and Analysis Panel (GDAP) Meeting was held concurrently with an International Space Science Institute (ISSI) workshop entitled "*Challenges in the Understanding of the Global Water-Energy Cycle and Its Changes*" in Bern, Switzerland, from 26–30 September 2022. The workshop provided a forum for fruitful scientific exchanges on the state of global energy and water cycle science before concluding with updates on all major GDAP projects and activities. Most Panel members and activity leads were able to join both the ISSI workshop and Panel meeting in person.

Given the strong overlap between the ISSI workshop theme and GDAP's mission to test consistency between global energy and water cycle data sets and identify observing system gaps, most of the week was devoted to presentations describing the state of the art in global energy-water cycle science and engaging discussions outlining a path to move the field forward. At the root of these discussions is the fundamental principle that radiative processes are key to the climate's water-energy cycle: climate is determined by the imbalances of solar radiative heating and long-wave radiative cooling. The circulation of the atmosphere and ocean, the environment on land, and the biosphere are all driven by local radiative imbalances. Changes in climate can be caused by alterations of the radiation budget at the top of the atmosphere or at the surface, such as those induced by changing amounts of greenhouse gases or aerosols in the atmosphere or by changing land surface properties. The sensitivity of the climate response to changes in the radiative forcing is determined by many feedback processes that alter the radiation budget, especially the processes involved with clouds and water vapor. Understanding and quantifying the climate response to changes in radiative forcings requires consistent, global-scale observations of the principal energy fluxes in the climate system.

Throughout the workshop, scientists from Europe, North America, and Japan assessed the current state of knowledge with respect to monitoring water-energy cycle changes from satellites. The workshop focused on coordinating space observations of the water and energy fluxes in the Earth system, evaluating their consistency, and advancing analysis methods to apply them in climate change assessments. Participants identified and discussed the observational challenges to improving our understanding of the global water and energy cycle with emphasis on observing capabilities in the next decade.

During the workshop, the experts took stock of the status of the different emerging themes related to the Earth's coupled water-energy cycle. The topics covered included estimates of water and energy in the atmosphere, global-scale changes in droughts and extreme precipitation, changes in the Earth's energy imbalance (EEI) and ocean heat storage, and changes in the surface temperature in response to the changing water-energy fluxes. It was demonstrated that the science community is now providing consistent satellite estimates of the global water and energy fluxes of the planet Earth from the bottom of the ocean to the top of the atmosphere over the last two decades. Observations now provide a consistent and objective picture of the global water and energy fluxes that explain the current Earth energy imbalance at the top of the atmosphere. This observational basis serves as a reference to better understand the subtle imbalances at stake among the Earth water and energy fluxes in the current climate. The challenge of the next decade is to detect, monitor, and understand how climate change modifies these balances in space and time (including EEI), leading to regional consequences that impact ecosystems and human communities. A key aspect to progress on this challenge is to improve the detection, the understanding, and the modeling of cloud changes and their relationship to radiative imbalances at the top of the atmosphere. The emergence of new observational approaches (e.g., mesoscale convective system tracking techniques) along with new modeling tools (e.g., convection-permitting models) shows promise for significant progress in the next decade. The workshop is expected to lead to a set of papers published as a volume of the Space Science Series of ISSI (SSSI) and, in parallel, in *Surveys in Geophysics*.

The GDAP Panel convened on Friday to welcome three new members, Helen Brindley, Maria Hakuba, and Benoit Meyssignac, and offer our warmest thanks to departing co-chair Rémy Roca for his six years of dedicated service. Hirohiko Masunaga was enthusiastically welcomed to succeed Rémy as GDAP Co-Chair. The Panel briefly discussed remaining membership needs, identifying a desire to establish liaisons with the Global Atmospheric System Studies (GASS) Panel and the GEWEX Hydroclimatology Panel (GHP) (Yunyan Zhang currently serves as a liaison to the Global Land-Atmosphere System Studies, or GLASS, Panel), before receiving project updates and conducting new business.

Claudia Stubenrauch summarized new foci of the Upper Tropospheric Clouds and Convection (UTCC) Process Evaluation Studies (PROES) and welcomed continued participation from GDAP members and affiliated scientists. With an eye toward future observing systems, there is an increased focus on analyzing the convective lifecycle and tracking convection using geostationary observations. GDAP and GASS will cosponsor a convective tracking workshop with the Atmosphere Observing System (AOS) project in the U.S. in 2023 to define the tools required to support convective lifecycle analyses in both satellite observations and global km-scale models (e.g., the DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains model, or DYAMOND). EarthCARE will hold a related "*2nd EarthCARE Modeling Workshop*" in Japan in March 27–29, 2023 that will consider the benefits and challenges of applying satellite simulators to bridge between global km-scale models and satellite observations. Simulators will also play an important role in GDAP's participation in the Warm Rain PROES. A goal of this initiative will be to coordinate modeling and observations to establish warm rain processes and impacts on radiative fluxes.

Participants of the 2022 GDAP Meeting and the ISSI Global Water-Energy Cycle Challenges Workshop

The second phase of the Water Vapor Assessment is concluding and has generated several papers in a special issue of *Atmospheric Chemistry and Physics* (https://acp.copernicus.org/articles/special_issue1118.html). Highlights include a robust assessment of the quality of upper tropospheric humidity products, comparisons of water vapor profiles over stratocumulus and in subsiding regions against GPS radio occultation estimates, analysis of the short-term variability in boundary layer water vapor, and a characterization of the consistency between reference water vapor observations. It was determined that there is no immediate need to initiate a third phase of the Water Vapor Assessment. While a follow-on assessment may be warranted in the future as water vapor data sets continue to evolve, the current state of the field has been sufficiently well-documented in the first two assessments to justify a pause in this activity.

The GDAP Earth's Energy Imbalance (EEI) Assessment continues to advance under the leadership of Benoit Meyssignac and Tim Boyer. The effort addresses the critical need for coordinating independent EEI estimates and establishing their uncertainties on a range of time and space scales. It is encouraging that independent estimates from top-down (satellite-based) and bottom-up (in situ) approaches are converging on annual scales. Several papers are in preparation or review documenting initial findings from the group. A second community workshop to consolidate results and advance new objectives under the EEI Assessment is planned for May 15–18, in Frascati, Italy (https://www.wcrp-esa-eeia-2023.org/).

Ground networks continue to provide important reference observations for anchoring GDAP science. Baseline Surface Radiation Network (BSRN) co-chair Christian Lanconelli presented outcomes from the BSRN meeting held in Vispra, Italy, in June 2022. A highlight from that meeting was the notification that the BSRN was recently approved as a Global Climate Observing System (GCOS) affiliated network. Other new activities within the vibrant BSRN community include defining a new longwave reference standard, establishing best practices for ocean-based radiation measurements, supporting satellite retrievals, and pioneering a suite of value-added products at some network sites. Plans to initiate a satellite working group in BSRN to strengthen the links between space-based and ground-based radiation measurements are ongoing.

The International Satellite Cloud Climatology Project–Next Generation (ISCCP-NG) initiative is also regaining momentum after the pandemic. Project lead Andrew Heidinger indicated that a prototype gridded Level 1 (L1G) data set for the full geostationary ring (GEO-ring) of advanced imagers has been produced for the year 2020 at 0.05 degree and 30-minute temporal resolution. Initial feedback has been positive, and experiments have begun to derive Level-2 (L2) cloud from the L1G prototype. To maximize utility for future applications, however, it will be important to determine whether the current time and space resolution is sufficient for applying modern convection tracking algorithms. ISCCP-NG has been well received by agencies internationally, and the National Oceanic and Atmospheric Administration (NOAA) and European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) have pledged to ensure continued progress. A second international ISCCP-NG workshop is planned for 2023 focusing on gathering feedback regarding the prototype L1G and the development of a corresponding suite of L2 products. GDAP will continue to support the ISCCP-NG project, help coordinate international meetings, report its status to the GEWEX Scientific Steering Group, and advertise the project to the broader cloud science community.

In the next year, it is anticipated that GDAP will initiate new cross-cutting activities with GLASS, GASS, and GHP. The Integrated Product (IP) workshop originally planned for spring 2020 has been resurrected and will serve to kick off a multi-scale, land-atmosphere closure initiative with GLASS and GHP in Toledo, Spain, in spring 2023. The UTCC PROES has bridged GDAP and GASS in the past, and this cross-panel coordination will continue as the activity focuses on understanding cloud, precipitation, and radiative processes over the full convective lifecycle. This activity will leverage significant recent advances in tracking convection in contemporary multi-channel geostationary observations (ISCCP-NG) to output from km-scale models (DYAMOND). To accelerate progress in global hydrologic modeling and process studies, GDAP and GHP will pursue a cross-panel activity starting in 2023 to document the capability of high time and space resolution satellite precipitation data sets to capture rainfall variability and extremes over the areas addressed by current and planned Regional Hydroclimate Projects (RHPs). These data may, in turn, fill an observation gap in regions where ground-based measurement infrastructure is not well established (e.g., Central Asia). Finally, GDAP is seeking to increase the breadth of knowledge on the Panel by adding members with expertise in global ground radar networks, land surface measurements [including land surface temperature (LST)], and ocean-atmosphere fluxes. Nominations are encouraged from individuals with expertise in any of these areas, especially those who complement the gender, ethnic, and geographic diversity of the Panel.