GEWEX NEWS

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William B. Rossow Symposium Highlights Scientist's Exceptional Career

William Rossow was recognized at the Symposium on Clouds, Their Properties and Their Climate Feedbacks for his many contributions to planetary and atmospheric science over his 40-year career. As project manager for the first GEWEX project, he led the development and production of global cloud products for the International Satellite Cloud Climatology Project (ISCCP) for 30 years. The ISSCP data set constitutes the longest global cloud record. Dr. Rossow has been a member of the GEWEX Scientific Steering Group, chaired the GEWEX Radiation Panel (GRP; now the GEWEX Data and Assessments Panel, GDAP) for seven years and remains an active member in GDAP. For more information about the conference and its results, see page 5.

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Commentary

International Collaborations Contribute to GEWEX Mission

Peter van Oevelen
Director, International GEWEX Project Office

The month of October was a busy travel month as I took the opportunity to visit colleagues in the Republic of Korea and Japan as part of my trip to attend the GEWEX Hydroclimatology Panel (GHP) meeting in Nepal. I cannot highlight everything, so I am presenting a brief selection of the many inspiring experiences I had. In particular, I was very pleased at the renewed energy in the Central Asian region (covering the Hindu-Kush Himalayas) regarding geophysical and climate research. The Chinese government's plans for considerable investment in research in this region are impressive, as are the efforts of the Korean National Meteorological Satellite Center and its plans for Earth observation missions. No doubt this could lead to improved global observational products under the GEWEX umbrella, including the International Satellite Cloud Climatology Project (ISCCP) and many others.

It is crucial that Earth observation efforts are maintained, particularly longer-term programs such as the satellites operated by numerous weather agencies and the European Space Agency's (ESA) Sentinel missions. These endeavors and similiar ones should be part of a clear, long-term vision that includes strong application and operational implementation aspects, and can only be sustained if corresponding and relevant in situ networks are also supported. Of course, this is one of the pillars of the GEWEX community, and I cannot stress enough that the only way to continue these efforts is a relentless push to continue funding. Agencies must understand that important scientific research is built upon a foundation of often tedious, laborious and repetitive data collection and analysis, which is neither glamorous nor fashionable. Although this may be surprising to research scientists, most of the general public does not know about the role of observational networks and the implications of reductions to these networks (e.g., meteorological satellites) to weather forecasts, flooding, hurricanes and other geophysical hazards and phenomena.

Given the above, it was nice to be informed that new meteorological stations are being installed in the Himalayas in hard-to-reach areas where we currently lack many of the observations we need. This was one of the aspects highlighted at the GHP meeting held jointly in Kathmandu with a Third Pole Environment (TPE) Program workshop. I'd like to take the opportunity here to express my thanks to my colleagues at the TPE Project Office in Beijing, especially Dr. Ailikun, and the local host Professor Deepak and his colleagues from Tribhuvan University, for handling the organization of this very productive gathering. Find out more about the meeting on page 19. The collaboration with TPE and our Asian colleagues is one that holds tremendous potential for exciting new research and a great opportunity to stimulate and help build research networks and expertise in this region.

Another issue I have renewed appreciation for after my trip is the need for climate researchers to examine not only the predictive part of the climate problem, but also its context, including the climatological past and societal aspects of the present. My visit to Professor Axel Timmermann at the Center for Climate Physics at the Institute for Basic Science in Busan, Korea emphasized that. I would be very happy to see the GEWEX Regional Hydroclimate Projects include a well-defined facet that looks at the past, present and future, and utilizes detailed information from various sources, such as Paleolithic data from lake bed sediment cores. In places like the Lake Victoria region of Central East Africa, knowledge such as that could help greatly in understanding processes and the implications of current and future environmental changes in the area. No doubt Professor Timmermann and colleagues would be interested in collaboration on these fascinating aspects.

Throughout its history, GEWEX has maintained a strong relationship with space agencies, which is not surprising given the history and reason for the GEWEX project's existence. These relationships must continue into the future, as they are vital to our mission. I visited the Japan Aerospace Exploration Agency (JAXA) Earth Observation and Research Center (EORC) and met with Professor Nakajima, the Center's Director, and his colleagues, and discussed future collaboration. The continued presence of the National Aeronautics and Space Administration (NASA), JAXA and ESA representatives as ex officio members of the GEWEX Scientific Steering Group facilitates communication and international collaboration. It is essential to the GEWEX mission that our community be informed of ongoing and new programs at these agencies, and programs like GEWEX offer an opportunity for research and the exchange of information outside of the sometimes limiting or stringent official collaborative efforts of these agencies, as was envisioned when GEWEX was established.

In May 2018, we are holding our next GEWEX Science Conference in Canmore, Canada, which promises to be an exciting event in beautiful surroundings, combining interesting scientific presentations with many opportunities for interaction with old and new colleagues. Networking is important, and bringing together scientists from different generations and regions will be at the core of this meeting. GEWEX has teamed up with the Young Earth System Scientists (YESS) and the Young Hydrologic Society (YHS) to organize an Early Career Researcher Workshop before the conference, along with entertaining side events for all. See details on page 20. I hope to see you in Canmore to discuss the latest science and catch up with colleagues old and new!

Research Highlights

New Observational Metrics Link Convection to the Horizontal Structure of Cirrus Anvils

Reference: Protopapadaki, E.-S., C.J. Stubenrauch and A.G. Feofilov, 2017. Upper Tropospheric Cloud Systems Derived from IR Sounders: Properties of Cirrus Anvils in the Tropics. *Atmos. Chem. Phys.*, 17, 3845-3859, doi:10.5194/acp-17-3845-2017.

Science: Covering about 30 percent of the Earth, upper tropospheric clouds play a crucial role in the climate system by modulating the Earth's energy budget and heat transport. When originating from convection, they often form organized systems. A cloud system approach, which was based on physical properties retrieved from spaceborne hyperspectral infrared (IR) sounder measurements, made it possible to link the cirrus anvil properties of mature convective systems to the convective depth. In agreement with other studies, the size of the convective systems increases in general with convective depth. Moreover, this analysis revealed for the first time that the ratio of thin cirrus over total anvil area increases with increasing convective depth.

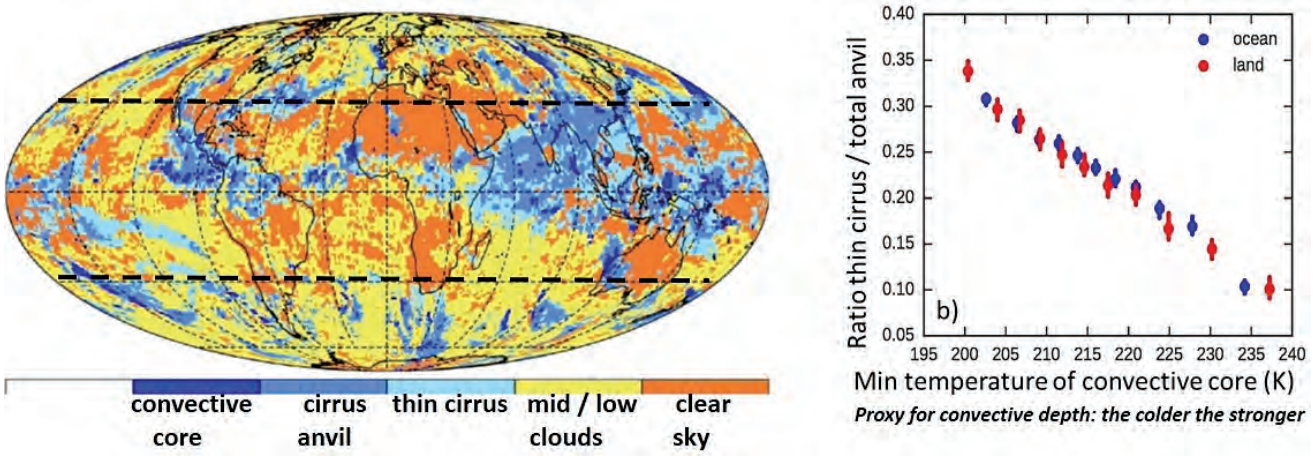
Impact: Changes in the horizontal emissivity structure in deep convective systems with changing convective depth might have important implications for upper tropospheric cloud feedbacks in relation to intensified convection in a warming climate. The observed relationships also provide promising observational diagnostics of convective detrainment processes in climate models.

This database of upper tropospheric cloud systems is complemented by other data within the framework of the GEWEX Process Evaluation Study on Upper Tropospheric Clouds and Convection (UTCC PROES, *GEWEX News*, May 2017), a new GEWEX activity to advance our understanding of climate-related physical processes of upper tropospheric clouds and convection.

Summary: Spaceborne hyperspectral IR sounder observations are well-suited for the retrieval of the physical properties of upper tropospheric (UT) clouds because they are also sensitive to cirrus (thin ice clouds), down to an IR optical depth of about 0.1, day and night. A cloud system approach based on retrieved physical properties made it possible to link the cirrus anvil properties of mature convective systems to the convective depth. The latter was approximated by the minimum temperature within the convective core. By using 13 years of statistics from measurements of the Atmospheric Infrared Sounder (AIRS), it was shown that colder convective systems (those rising higher) have a larger maximum rain rate (a tendency more pronounced over land), as well as larger cirrus anvils (a tendency more marked over ocean), in agreement with previous studies. Furthermore, the novel cloud system approach provides a unique opportunity to study the horizontal emissivity structure within anvils. In general, higher rising convective systems include more thin cirrus in their anvils. This provides promising observational metrics for studying detrainment processes.

Link to publication:
https://www.atmos-chem-phys.net/17/3845/2017

Recently publish a paper related to GEWEX research? We are interested in showcasing selected research highlights that feature recent and interesting results relevant to the GEWEX mission. For consideration, please summit your highlight at: *http://www.gewex.org/latest-news/research-highlights/*. If your article qualifies, it will be published on the GEWEX website and may be featured in *GEWEX News*.



Left: Snapshot of upper tropospheric cloud systems in July 2009, from the Atmospheric Infrared Sounder (AIRS). Right: The ratio of thin cirrus (effective cloud emissivity, $e_{cld} < 0.5$) to total anvil area of tropical convective systems (30°N–30°S) increases as the temperature of the convective core decreases. The latter is a measure of convective depth using 13 years of AIRS statistics.

Hydrology Section Student Subcommittee (H3S) Update on AGU Fall Meeting

This December, the American Geophysical Union Fall Meeting will be held in New Orleans, Louisiana. H3S and collaborators are organizing three workshops (in Room 342, 3rd floor) during the conference that provide attendees with opportunities to grow technically and socially within the broader geosciences community.

Workshop 1–First impressions count! (December 11, 3 PM)
In this practical workshop on introductions and opening conversations, participants are given strategies for forging respectful professional relationships. These will include pronouncing unfamiliar names, learning about respectfully introducing one's self and how to ask for gender pronouns.

Workshop 2–Forging successful partnerships between academia, industry and government (December 12, 3 PM)
Panelists with different backgrounds (non-profit, corporate, governmental and academic) will briefly discuss their work and typical job responsibilities, and will provide advice for creating successful partnerships.

Workshop 3–What next? Keeping motivation and an optimistic outlook! (December 13, 3 PM)
The uncertainty of a future beyond graduate studies can be uncomfortable. This session will help students prepare for what comes next with short presentations from invited speakers in different stages of their hydrologic career and a Q&A session. Speakers will outline a few difficulties they experienced and what kept them motivated to make the struggle worthwhile.

In addition to the workshops, H3S is organizing a **town hall meeting** (Rooms 228-230) on the evening of December 14 to provide students and early career scientists an opportunity to think about the future of the geosciences community. Topics will include questions such as: what challenges do you foresee in science in the next couple of years? In what direction do you think we should be heading? How do we improve the way we and others live and enjoy our science? What is the quality of life for science professionals? We invite everyone to submit an abstract for a short 5-minute talk that shows your perspective on these or related topics that are relevant to the future of the geosciences community. These short talks should serve to kick-start an interesting discussion.

Finally, the *Water Resources Research (WRR) Journal* and H3S will host a joint town hall meeting about the publishing process on December 11 from 12:30–1:30 PM in Rooms 211-213. Topics covered during this lunch session (food will be provided) will include (1) writing and submitting papers, (2) reviewing and (3) sharing science and advances in published papers. A panel including scientists, editors and students will give perspectives on these topics and answer questions.

Throughout the conference, H3S plans to challenge students with fun games via social media with small prizes for winners! For more details on our activities, keep an eye on our twitter account (@AGU_H3S). See you in New Orleans!

New GEWEX Scientific Steering Group Members

We welcome the following new GEWEX SSG members, whose terms begin in January 2018. For a listing of all the SSG members, see: *https://www.gewex.org/about/organization/scientific-steering-group/*.

Qingyun Duan

Dr. Duan is a professor of hydrology and water resources at Beijing Normal University (BNU), China. Prior to his current position, he worked at the U.S. National Oceanic and Atmospheric Administration's Hydrology Laboratory from 1991–2003 and Lawrence Livermore National Laboratory from 2004–2009. His research interests include hydrology and water resources management, hydrological model development and calibration, hydrometeorological ensemble forecasting and uncertainty quantification for large complex system models. His recent work includes the development of an uncertainty quantification software platform for large complex system models, Uncertainty Quantification Python Laboratory (UQ-PyL), and the BNU Hydrological Ensemble Prediction System (BNU-HEPS). He is a recipient of the Chinese "One-Thousand Talents Program" award, and a Fellow of the American Geophysical Union and the American Meteorological Society.

Byung-Ju Sohn

Dr. Sohn is a professor at the School of Earth and Environmental Sciences at Seoul National University in Korea. His research focuses on the study of radiation physics using satellite measurements to understand weather and climate phenomena. Dr. Sohn's recent work includes using infrared hyperspectral measurements to retrieve temperature and moisture profiles for application to data assimilation in the Unified Model system. He also applies long-term satellite-derived data to improve understanding of climate processes, and uses microwave measurements to detect climate change signals and sea-ice retrieval. Dr. Sohn was a member of the GEWEX Radiation Panel (GRP) from 2007–2011 and the GEWEX Data and Assessments Panel (GDAP) from 2012–2016. He is currently president of the International Radiation Commission of the International Union of Geodesy and Geophysics (IUGG) International Association of Meteorology and Atmospheric Sciences (IAMAS).

William B. Rossow Symposium on Clouds, Their Properties and Their Climate Feedbacks

George Tselioudis*
NASA Goddard Institute for Space Studies, NY, USA

The 3-day scientific symposium was organized by the National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies (GISS), the City University of New York (CUNY)/Remote Sensing Earth Systems Institute (CREST) and Columbia University, and was held at Columbia University on 6–8 June 2017. The motivation for the symposium was the recent retirement of William B. Rossow after 40 years of exceptional contributions on a wide range of planetary and atmospheric science topics. The objective of the symposium was to stimulate discussion on the progress that has been made over the past decades in understanding cloud properties, processes and feedbacks, and to explore strategies to tackle the issues that remain unresolved. The agenda and presentations are available at: *https://isccp.giss.nasa.gov/Rossow_Symposium/*.

William (Bill) Rossow has been a leader in the study of the complex interactions between atmospheric dynamics and the water and energy cycles, both on Earth and in planetary atmospheres. His quest started during his graduate school years at Cornell University, where his work focused on the clouds and dynamics of the atmospheres of Venus and Jupiter. His doctoral work contributed to the identification of the composition and provided the first physical characterization of the nature of Venus clouds. In the following years, he developed a theory of the difference in the organization of atmospheric general circulations between slowly and rapidly rotating planets and separated mean flow from wave propagation speeds in the upper atmosphere of Venus.

Turning his attention to Earth, Bill focused on clouds, radiation and the Earth's climate as Head of the Earth Observations Group at NASA GISS and as Head of the Global Processing Center for the World Climate Research Programme's International Satellite Cloud Climatology Project (ISCCP) since 1982. For more than 30 years he led the development and production of **global cloud products for the International Satellite Cloud Climatology Project (ISCCP), which now constitutes the longest global cloud record.** Bill also supervised the creation of ISCCP-FD, the first global data set of top-of-atmosphere (TOA) and surface radiative fluxes that resolves the diurnal, seasonal and interannual variations of cloud effects. He devoted a large portion of his scientific endeavors to applying innovative analysis methods to satellite data records, in order to understand the processes involved in determining the water and energy budgets of the Earth. Bill has been involved with GEWEX since its founding. He was a member of the GEWEX Scientific Steering Group and for seven years chaired the GEWEX Radiation Panel (GRP; now the GEWEX Data and Assessments Panel, GDAP). He was an active member of GDAP until his retirement.

After welcoming remarks by Gavin Schmidt on behalf of NASA/GISS and Reza Khanbilvardi on behalf of CUNY/CREST, the presentations began with a session that reviewed the **30-year history of ISCCP data**, which focused on the challenges of producing the data, the achievements and the lessons learned. Several speakers noted in their presentations that the long time record and high time resolution of ISCCP data allowed for important advances in the understanding of the time rate of change of cloud properties and processes, obtained through process-oriented analyses of the data. It also led to advances in the understanding of the competing impacts of longwave (LW) and shortwave (SW) cloud radiative effects. At the same time, it was emphasized that the analyses provided interesting physical symmetries related to clouds that still need better explanations. For example, **why do the SW and LW radiative effects of clouds on the planetary radiation budget nearly cancel in the tropics? Why is there almost a balance in northern and southern hemisphere total albedo even though the surface albedos are so different?** The sense of the participants was that there is large potential for further growth in the field. The global mapping of high resolution spatial, temporal and spectral data from geostationary satellites will soon be possible, and this will allow further insights into cloud processes. There is, therefore, a need to increase the collaborations between geostationary and low Earth orbiting satellite data analysis, and between observational and model development and analysis efforts.

The session on **Clouds and Climate Processes** included presentations that covered a range of cloud feedbacks that occur in different Earth climate regimes. In the tropical regions, it was shown that the existence of an "apparent iris effect" was not a dominant factor in the intermodel spread in climate sensitivity, while another presentation noted that the use of Radiative Convective Equilibrium modeling, while a useful tool, does not resolve important scales such as organized convection. In the subtropical and lower midlatitude regions, it was shown that cloud changes are dominated by Hadley cell expansion, which results in increases in low cloud cover and cloud SW cooling. Climate models, on the other hand, tend to produce cloud cover decreases and significant shortwave warming with poleward Hadley edge shifts. In the mid-latitude regions, models across the board show a strong negative cloud phase feedback with climate warming, resulting from ice to water particle transitions. This feedback is not properly constrained by observations, due to a lack of reliable cloud phase retrievals at global scales. The participants also emphasized the need to better resolve vertical velocity variability at all time and space scales, in order to improve our understanding of the processes involved in cloud dynamics interactions and the resulting radiative feedbacks.

**With contributions from the Symposium chairs and rapporteurs: Chris Kummerow, Jimmy Booth, Johnny Luo, Hanii Takahashi, Claudia Stubenrauch, June Wang, Bernard Lipat, Christian Jakob and Jackson Tan.*

The session on **New Data Sets and Retrieval Methods** covered improved cloud products from existing and new satellite missions, as well as original capabilities in radiative transfer. Since ISCCP data production has been transferred to the National Oceanic and Atmospheric Administration (NOAA), it was announced that new cloud products, at a higher spatial sampling of 10 km, would be released before the end of 2017. During the last 35-year period, the number of satellites used in the cloud retrievals has increased considerably (33 satellites by 2017). The plans for the new ISCCP-FH atmospheric flux profile product are to provide radiative fluxes at the surface, three atmospheric layers, and at TOA at a spatial resolution of 110 km. However, despite the fact that the code was transferred, the NOAA climate data record (CDR) program was cancelled, and there is a need for the community to advocate for funding for the production of ISCCP-FH. A presentation demonstrated that the ten spectral bands of the Advanced Imager on the new Japanese geostationary satellite Himawari, allow the study of the diurnal cycle of upper tropospheric clouds, including cirrus clouds, and the life cycle of deep convective systems over Asia and the Western and Central Pacific. The capabilities of the upcoming European Space Agency (ESA) Earth Cloud Aerosol and Radiation Explorer (EarthCARE) mission were discussed at length and it was noted that, in addition to cloud liquid water path and particle phase, EarthCARE is expected to provide vertical air motion, particle fall speed and mass flux, which will be of particular interest for evaluating cumulus parameterizations of convection. The capability of the Deep Space Climate Observatory (DISCOVR) spacecraft to retrieve the likelihood of occurrence of horizontally oriented ice crystals and their contribution to the Earth albedo was also presented. The session discussions revealed that on one hand there are more products from single instruments, but on the other hand there are few initiatives to combine measurements from several instruments for a synergetic retrieval. While internationally coordinated assessments (in particular, conducted by GEWEX) of single products (clouds, precipitation, fluxes, water vapor, aerosols) are regularly undertaken, a new step forward could be to develop integrated products (coherent retrieval of several products used for flux closure) and synergetic databases (building synergy from existing products). These are essential for process studies, such as the Process Evaluation Study (PROES) undertaking recently initiated by GEWEX.

In the session that examined **Cloud Radiative Effects and Microphysical Processes**, the application of clustering techniques was shown to identify variability regimes in air-sea fluxes of heat, moisture and carbon. The regime separation showed that latent heat fluxes maximize under clear sky conditions, due to the dry boundary layer conditions and despite the lower wind speeds. Analysis of CloudSat/Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) retrievals showed that clouds constitute nearly 10% of the global latent heat release and that multi-layer clouds are the largest contributor to the total cloud radiative forcing at TOA. Several studies examined the effects of aerosols on cloud radiative properties

Participants at the William B. Rossow Symposium on Clouds, Their Properties and Their Climate Feedbacks. Bill Rossow is standing in the center in the back of the room. On the right side of the screen is a younger Bill Rossow.

and their impact on convective processes. It was reported that while aerosols overall may inhibit convection by warming the lower atmospheric layers, some aerosol types may enhance convection by suppressing warm rain processes. Furthermore, in convective downdrafts occurring over the Amazon region in South America, cloud droplets are observed to be larger outside the aerosol plume than they are inside the plume.

The final session on **Clouds at Weather Scales** dealt with a wide range of issues, including organized convection, mesoscale convective systems, convective transitions, climatology and variability of cloud types and precipitation, global circulation model (GCM) evaluation of cloud-related processes and fusion of multiple data sets. It was shown that the long record of cloud observations from a multitude of space-borne instruments has given rise to a broad collection of tools of varying maturity to probe various aspects of the atmosphere and the climate system. These include the well-studied ISCCP Weather States or Cloud Regimes and the process-oriented convective and extratropical cyclone tracking data sets, to cloud property retrievals from more recent instruments such as the Moderate Resolution Imaging Spectroradiometer (MODIS), the Multi-angle Imaging SpectroRadiometer (MISR) and the Atmospheric Infrared Sounder (AIRS). It was noted that to fully exploit the existing data, studies should focus on the integrative use of several diverse data sets, such as using active retrievals from CloudSat and CALIPSO to evaluate the vertical cloud structure of ISCCP and MODIS passive retrievals. Models and reanalysis can, with understanding of their limitations, be used to supplement observations. This approach has proven difficult to achieve mainly due to the diverse set of funding often targeted on single missions. The participants stressed that there is a pressing need to understand the full range of convective processes (e.g., mesoscale organization, lifecycle, transitions) and represent them in GCMs. This is a longstanding problem but the need to address it has gained importance due to its role in accurate prediction and projection of precipitation. There are several bold initial attempts, but complete testing and integration remains elusive. The effort expended on improving the GCMs remains minute compared to the investment in observations and the use in models, probably explaining the excruciatingly slow progress.

The symposium closed with a discussion session chaired by Bill Rossow, during which it was stressed that, thus far, ISCCP remains the only global long-term data set derived from a combination of geostationary and polar orbiters. The need for multiplatform data sets could be remedied by soliciting the funding agencies to prioritize multi-instrument retrievals. At present, the international satellite agencies are focusing on long-term climate data records from many separate instruments, which need recalibration, in particular in the case of satellite instrument changes. GEWEX could take the lead in advocating for integrated satellite products. The NASA decadal survey for Earth science might also be the place to emphasize the importance of synergetic retrievals and analyses. Since the task is complex, it needs international cooperation, building upon the heritage of what was already achieved by ISCCP, as well as the time and effort to produce the best data sets possible.

Understanding Global Rainfall Using the PERSIANN Climate Data Record: An Introduction to CHRS RainSphere

Soroosh Sorooshian, Phu Nguyen, Mohammed Ombadi, Eric Jay Shearer, Phat Huynh, Thanh Pham, Hoang Tran, Andrea Thorstensen, Hamed Ashouri, KuoLin Hsu, Amir AghaKouchak, Dan Braithwaite and William S. Logan

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Data are imperative to the development of a knowledge-based society and the advancement of science, and it is incumbent on research institutions to ensure that data are easily accessible to the general public. The Center for Hydrometeorology and Remote Sensing (CHRS) at the University of California, Irvine has created CHRS RainSphere, an integrated system for global satellite precipitation data and information. The website can be accessed at: *http://rainsphere.eng.uci.edu/* (Nguyen et al., 2017a).

CHRS RainSphere is a powerful educational system with a wide range of user-interactive tools. It is designed to enhance general knowledge about climate and encourage public inquiry by providing historical records, analytical data results and future projections of arguably the most important element of the hydrological cycle—precipitation.

Data Inputs

The two main inputs to RainSphere are the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Network–Climate Data Record (PERSIANN-CDR) historical record and Coupled Model Intercomparison Project, Phase 5 (CMIP5) future projections. PERSIANN-CDR is a historical record of satellite-based observations of precipitation dating back to 1983 (Ashouri et al., 2015). Its algorithm is based on the original PERSIANN algorithm (Hsu et al., 1997, 1999; Sorooshian et al., 2000). CMIP5 future projections is a data set of future rainfall based on three carbon emission scenarios: Representative Concentration Pathway (RCP) 2.6, RCP4.5 and RCP8.5 (Taylor et al., 2012; Nguyen et al., 2017b).

Data Analyses

The data analyses performed by RainSphere include calculating average precipitation rate, fitting a linear regression model to the data over a specific time period and testing for monotonic trends in the precipitation record through the use of the non-parametric Mann-Kendall test (Mann, 1945; Kendall, 1976). The Mann-Kendall test is performed at a significance level of 0.05.

Using RainSphere

RainSphere is designed to be user friendly and support data queries at different spatial and temporal scales. A tutorial in

video and slideshow formats that demonstrates how to navigate and utilize the tools of RainSphere can be found in the navigation bar under the heading "Tutorial" in the main RainSphere interface. In the left-hand sidebar, there are the Map Layers, Rain Information and Rain Layers tools. The Map Layers tool is used to overlay a border map layer on the base map. Its options include maps by country borders, political division borders (such as states and providences), continental basins, major river catchments and other smaller hydrological subdivisions. The Rain Information tool is used to switch between historical records and future projections of precipitation data. The Rain Layers tool is used to overlay a rainfall layer on the base map. The user can use this tool to create a data layer that displays the accumulative or average precipitation data for a set time period (for as few as a couple of days to as long as the length of the data set).

Features

In addition to the options of rainfall visualization indicated above, RainSphere includes three new powerful tools, which can be used for further statistical analysis. All these tools can be used with both the PERSIANN historical data and CMIP5 future projection data.

• *Rain Layers Comparison*

The Rain Layers Comparison tool is an ergonomically convenient instrument, which can be used to visualize and compare two precipitation layers side by side. To use the tool, create two rain layers using the Rain Layers tool, and then pick the layers from the dropdown menus labeled "Left Window" and "Right Window." Figure 1 shows a comparison between the cumulative rainfall for all of 2013 and the average annual rainfall climatology over California. The side-by-side nature of the Rain Layer Comparison tool makes it immediately clear that the annual precipitation of 2013 was considerably lower than the rainfall climatology average.

Additionally, the Rain Layers comparison tool can be used to present the difference in the two layers' precipitation rates as a percentage of the first layer precipitation. The resulting map layer is color coded for easy visualization of the data, with the color blue representing a negative difference of RainLayer R1 (formerly labeled "Left Window") compared to RainLayer R2 (formerly labeled "Right Window"), and the color red representing a positive difference. This tool can be accessed by choosing it from the dropdown menu under the Rain Layers comparison tab. Figure 2 shows the difference of 2013 precipitation from the rainfall climatology average; the severity of the 2013 drought is immediately apparent, with most areas of California showing more than a 60% decrease in rainfall.

• *Rain Trend*

With the ongoing climate change debate and continuing questions about which variables significantly contribute to it, this tool provides a visualization of trend analysis available at different spatial scales. These spatial scales include pixel (which corresponds to an area of 0.25°× 0.25°), country, political divisions and various water basin boundaries. The trend analysis is performed using the Mann-Kendall test at a 0.05 significance level as described earlier. Figure 3 shows a rainfall trend map at country scale. Countries (along with other divisions) overlaid with hashed lines indicate that the rainfall trend is not statistically significant. Many countries are overlaid with these lines and therefore are not experiencing a significant trend in precipitation change.

• *Rain Statistics*

This tool can be used to generate statistical reports of precipitation over different temporal scales from days to years and location boundaries including pixel size, political and hydrological boundaries and user created rectangles. These reports include a bar chart that displays rainfall amounts per time division (year, month or day, depending upon the time domain chosen), a temperature curve, a line that displays the average precipitation over the entirety of the query time and the trend result according to the Mann-Kendall Test. Figure 4 shows the data table that is displayed with the Rain Statistics Tool. Data from the report can be exported to comma-separated values (CSV) files to provide users with an opportunity for further analysis.

References

Ashouri, H., K.L. Hsu, S. Sorooshian, D.K. Braithwaite, K.R. Knapp, L.D. Cecil, B.R. Nelson and O.P. Prat, 2015. PERSIANN-CDR: Daily Precipitation Climate Data Record from Multi-satellite Observations for Hydrological and Climate Studies. *Bull. Amer. Meteor. Soc.*, 96, 69–83, doi: *http://dx.doi.org/10.1175/BAMS-D-13-00068.1*.

Hsu, K., H.V. Gupta, X. Gao and S. Sorooshian, 1999. Estimation of physical variables from multichannel remotely sensed imagery using a neural network: Application to rainfall estimation. *Water Resour. Res.*, 35, 1605–1618, doi:10.1029/1999WR900032.

Hsu, K., X. Gao, S. Sorooshian, and H.V. Gupta, 1997. Precipitation estimation from remotely sensed information using artificial neural networks. *J. Appl. Meteor. Climatol.*, 36, 1176–1190, *https://doi.org/10.1175/1520-0450(1997)036<1176:PEFRSI>2.0.CO;2*.

Kendall, M., 1976. *Rank Correlation Methods,* 4th ed. Griffin, 202 pp.

Mann, H., 1945. Nonparametric tests against trend. *Econometrica*, 13, 245–259, doi:10.2307/1907187.

Nguyen, P., S. Sorooshian, A. Thorstensen, H. Tran, P. Huynh, T. Pham, H. Ashouri, K. Hsu, A. AghaKouchak and D. Braithwaite, 2017a. Exploring Trends through "RainSphere": Research data transformed into public knowledge. *Bull. Amer. Meteor. Soc.*, 98, 653–658, *https://doi.org/10.1175/BAMS-D-16-0036.1.*

Nguyen, P., A. Thorstensen, S. Sorooshian, Q. Zhu, H. Tran, H. Ashouri, C. Miao, K. Hsu and X. Gao, 2017b. Evaluation of CMIP5 Model Precipitation Using PERSIANN-CDR. *J. Hydrometeor.*, 18, 2313–2330, *https://doi.org/10.1175/JHM-D-16-0201.1.*

Sorooshian, S., K.-L. Hsu, X. Gao, H.V. Gupta, B. Imam and D. Braithwaite, 2000. Evaluation of PERSIANN system satellite-based estimates of tropical rainfall. *Bull. Amer. Meteor. Soc.*, 81, 2035–2046, *https://doi.org/10.1175/1520-0477(2000)081<2035:EOPSSE>2.3.CO;2*.

Taylor, K.E., R.J. Stouffer and G.A. Meehl, 2012. An overview of CMIP5 and the experiment design. *Bull. Amer. Meteor. Soc.*, 93, 485–498, doi:10.1175/BAMS -D-11-00094.1.

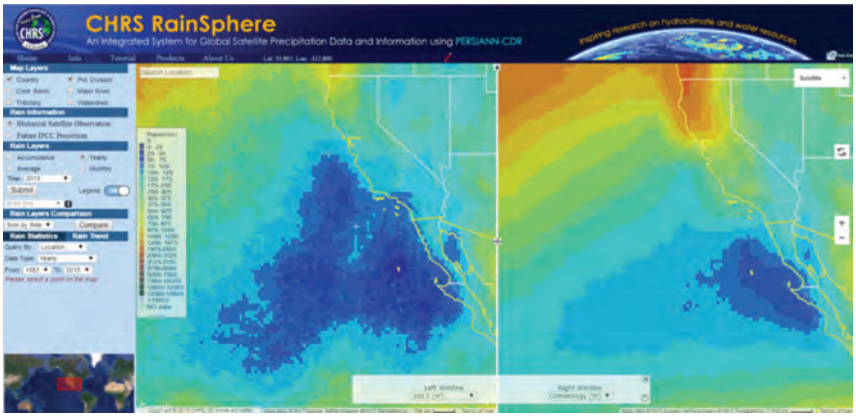


Figure 1. Side by side comparison of the accumulative rainfall over the West Coast in 2013 versus the average rainfall climatology.

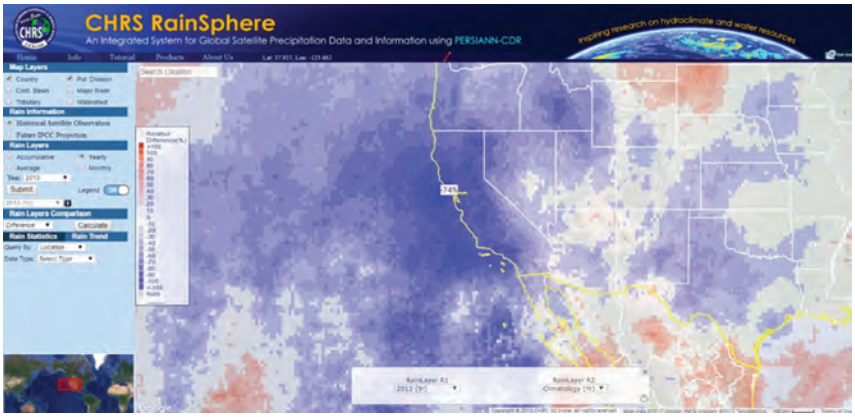


Figure 2. Statistical difference of the accumulative rainfall over the West Coast in 2013 versus the average rainfall climatology.

Figure 3. Past rain trends for all countries south of the 60°N line of latitude. Note that countries overlaid with hashed lines have no statistical significance in their rainfall trend.

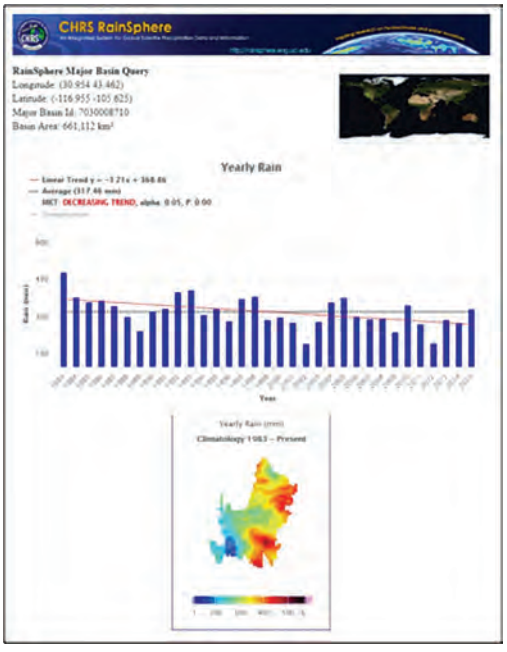


Figure 4. Rainfall data and climatology trends for the Colorado River Basin for 1983–2015.

Meeting/Workshop Reports

Joint GEWEX/iLEAPS Session at 5th iLEAPS Science Conference

Oxford, UK
11 September 2017

Richard Harding[1], Peter van Oevelen[2], Jan Polcher[3] and Alberto Martinez[1]

[1]Centre for Ecology and Hydrology, Wallingford, UK; [2]International GEWEX Project Office, Washington, DC, USA; [3]Laboratoire de Météorologie Dynamique du CNRS, Paris, France

Half of our major rivers are moderately or severely impacted by human activities—from impoundments and extraction to the reduction of flows and changes in the seasonal regime. Irrigation use is the major reason for water extraction from rivers, reservoirs and groundwater, although use for industry and drinking water is growing fast. The irrigated area of the world occupies only a small percentage of the land area but produces about 40 percent of our food and regionally can be large, particularly in semiarid "hotspots." The area and intensity of irrigation is likely to increase in the future as we struggle to feed up to 11 billion people in the next few decades.

There are many tens of thousands of dams worldwide that store approximately 8000 km^3 of water—a significant fraction of the global annual river flow. Some of the impacts of these dams are directly coupled to the atmosphere, influencing, for example, temperature extremes and evaporation, and ultimately, clouds and rainfall. Dam impoundments and groundwater extractions also have a significant impact on sea level rise. Pokhrel et al. (2012) estimate that impoundments cause a lowering of sea level by 0.4 millimeters per year and groundwater extractions a rise of 1.1 millimeter per year.

The joint session of the integrated Land Ecosystem-Atmosphere Processes Study (iLEAPS) and GEWEX at the 5th iLEAPS Science Conference was the next step in the GEWEX Hydroclimatology Panel (GHP) and Global Land/Atmosphere System Study (GLASS) crosscutting project, "Human Regulation of the Water Cycle," which builds upon the conclusions of the GHP/GLASS workshop held in Gif-sur-Yvette, France in September 2016 (see report in November 2016 issue of *GEWEX News*). A global research project of Future Earth, iLEAPS provides an understanding of how interacting physical, chemical and biological processes transport and transform energy and matter through the land-atmosphere interface. The iLEAPS Science Conference provided an opportunity to review and report on the conclusions of last year's meeting and assess the progress made over the past 12 months. In addition, the iLEAPS community provided new insights into the discussion of the human dimension by including expertise in atmosphere chemistry, the carbon balance and the biosphere.

Peter Greve reported on the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) study that uses a probabilistic approach to estimate global water scarcity with different socioeconomic pathways (SSPs) and climate-forcing scenarios (Representative Concentration Pathways, RCPs) for the first half of the 21st century. The results show that both average water scarcity and the associated range of uncertainty will generally increase in the future in most regions of the world, including many intensively cultivated agricultural areas. Most of the uncertainty in the projections can be attributed to differences in the employed hydrological impact models rather than to projected socioeconomic development.

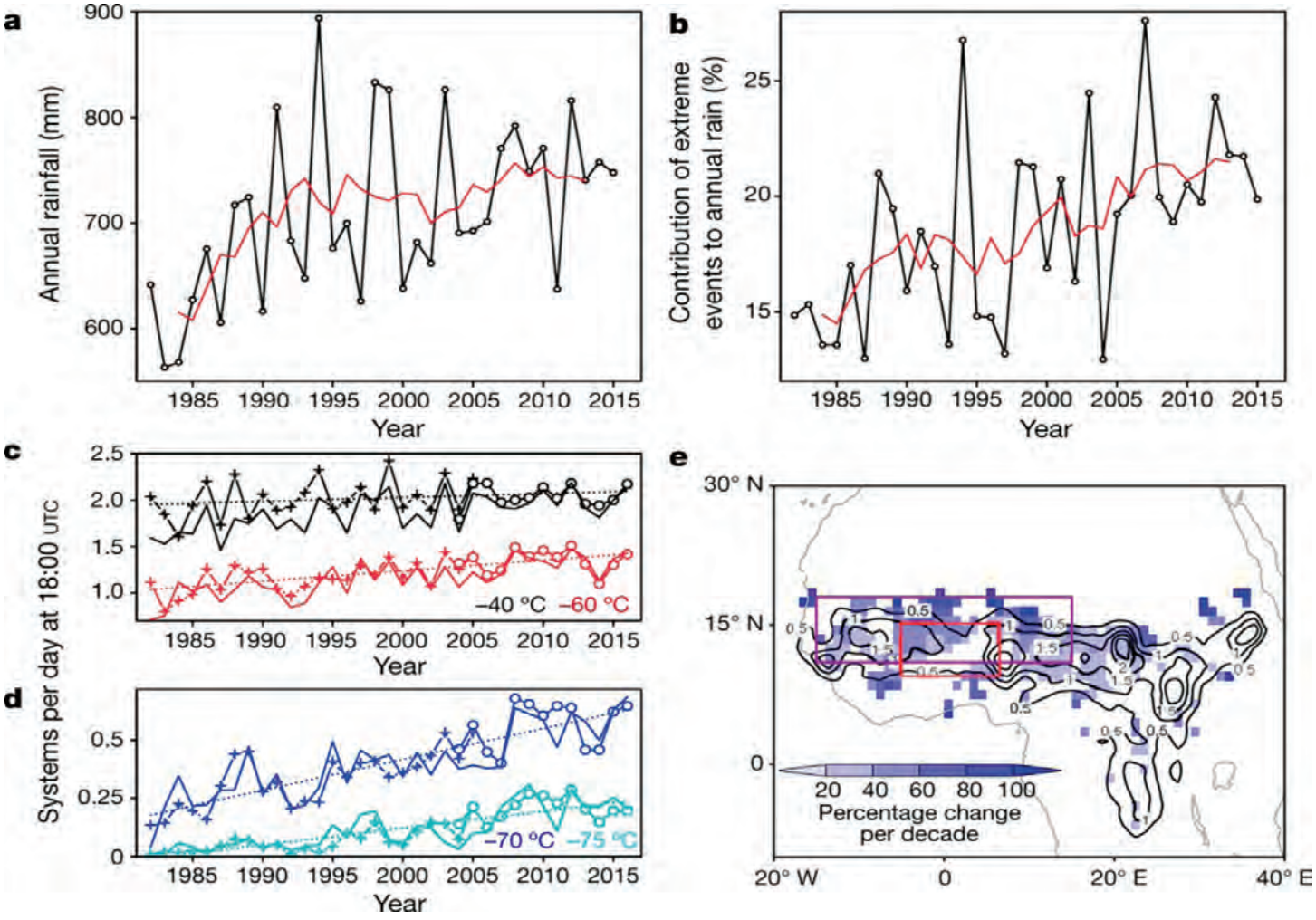
Freshwater flowing into the Mediterranean Sea is an important factor in the large-scale circulation of this closed basin, as well as for maintaining marine and coastal ecosystems. Due to the uncertainties from ungauged rivers, human activities and measurement of water flows at river outlets, estimating the freshwater input into the Mediterranean Sea has large uncertainties. Previous studies estimated freshwater inflow into the Mediterranean Sea, either by combining simple annual water balance and, where available, observations (only providing annual mean discharge values), or by land surface models (LSMs) forced by atmospheric conditions (affected by model uncertainties). In a reported study, data assimilation techniques were used to merge model output [e.g., Organizing Carbon and Hydrology In Dynamic Ecosystems (ORCHIDEE) LSM developed at Institut Pierre Simon Laplace] and observed river discharge from the Global Runoff Data Centre (GRDC, about 630 stations) to obtain optimized river discharges for all rivers contributing to the Mediterranean Basin. This approach compensates for systematic errors of the model, as well as missing processes. It provides estimation of the riverine input into the sea at high temporal and spatial resolution (1979–2013).

LSMs used in Earth regional and global system models have the capability to simulate natural water, energy and carbon cycles over the continents. These models simulate the state variables of the surface, the fluxes exchanged with the atmosphere and the river discharge into the oceans. LSMs have evolved rapidly over the last 20 years and are now the tool of choice to perform reanalysis of surface states and to study land-surface processes in interaction with the other components of the Earth system. However, these models, in contrast to global hydrological models, mostly neglect the regulation of the water cycle of the continents and vegetation that is done to benefit agriculture and industry. This is especially true in the food baskets of the world. These anthropogenic processes need to be integrated in models to make LSM predictions for climate change relevant to society. This evolution will probably be more transformational than when the carbon cycle was introduced. This change has been

implemented into ORCHIDEE. The introduction of value classes for all surface water flows allows implementation of operating rules for human water usage, which maximize the benefits of water for human activities. Simple test cases show this increases the water usage for irrigation and yields more realistic river discharge. There are still numerical difficulties for implementing human processes in LSMs; one example is the propagation of unsatisfied water demands, an essential element in the operating rules of dams.

In West Africa, any trends in rainfall characteristics have potentially important impacts on agriculture. Crops are predominantly rainfed, and yields are sensitive to the timing of rainfall within the season, as well as season length and total rainfall. Moreover, changes in rainfall intensity influence runoff and soil erosion, with impacts on yields through nutrient losses. Chris Taylor documented observed changes in the intensity of Sahelian Mesoscale Convective Systems (MCSs) over the 35-year satellite record. These systems provide around 90 percent of Sahel rainfall, and can be readily identified from sub-hourly cloud-top temperature images from Meteosat. The analysis shows a remarkable downward trend in cloud-top temperatures within MCS, which has continued since the so-called recovery of seasonal rainfall from the 1970s (see figure below). The study finds a tripling in the frequency of MCSs observed over the Sahel during this period with a tendency towards more intense convection in late afternoon and evening, in turn creating larger,

Observed Changes in the Intensity of Sahelian Mesoscale Systems



Trends in Mesoscale Convective Systems (MCS) and rainfall across the Sahel. (a) Annual rainfall, (b) contribution of extreme events to annual rainfall, (c) and (d) regional mean MCS frequency (for different temperature thresholds), and (e) significant trends in MCS cloud cover. For more details, see Taylor et al., 2017.

longer-lived systems overnight. Assuming that the present-day physical relationships linking Saharan warming with Sahelian MCS intensity hold in the future, extreme daily rainfall totals are likely to continue to rise rapidly, regardless of (highly uncertain) seasonal mean rainfall projections (Taylor et al., 2017).

Land-use and land cover changes (LULCC) can have significant biophysical impacts on regional precipitation, including monsoon rainfall. However, most modeling studies are based on the use of only one global or regional climate model that focuses on one specific region and/or apply different idealized deforestation and afforestation scenarios. Benjamin Quesada reported a series of global simulations performed with and without LULCC from five Earth System Models (ESMs) under a common and realistic LULCC scenario (the Representative Concentration Pathway RCP8.5), Vienna University of Technology finding that future LULCC significantly reduces monsoon precipitation in at least four out of eight monsoon regions (Quesada et al., 2017). While monsoon rainfalls are likely to intensify under future global warming, the biophysical effects of LULCC substantially weaken future projections of monsoon rainfall by 9 percent (India), 12 percent (East Asia), 32 percent (South Africa) and 41 percent (North Africa), with an average of approximately 30 percent for projections across the global monsoon region.

A similar strong contribution is found for biophysical effects of past LULCC to monsoon rainfall changes since the preindustrial period. Rather than remote effects (e.g., Intertropical Convergence Zone shifts or meridional heat transport), local land-atmosphere interactions, implying a decrease in evapotranspiration, soil-moisture and clouds along with more anticyclonic conditions, could explain this reduction in monsoon rainfall. As only about two-thirds of global climate models account for LULCC (IPCC et al., 2013), the current average projections of monsoon rainfall could be overestimated. In consequence, to increase confidence and robustness in monsoon projections and climate mitigation strategies, it is important to consider LULCC carefully for future projections of the hydrological cycle.

The world faces a perfect storm of limited water, energy and food. Rising population and consumption against a background of limited water and land threaten a major environmental and humanitarian disaster. Already, one-fifth of the world's population lives in countries with water scarcity, leading to unsustainable use with decreasing groundwater levels and decreasing quality of freshwater systems. Freshwater is already the most degraded of the ecosystems. The pressures will exacerbate with climate change: although global precipitation is likely to increase regionally we may see decreases, and variability is likely to increase with more intense rainfalls—features that will put more pressure where water resources are already stretched.

There are also other, more indirect impacts of man's interventions in the terrestrial water cycle. Approximately one-third of the observed sea level rise can be attributed to the dewatering of aquifers, ameliorated to an extent by increases in impoundments in reservoirs. Reduced outflows to the oceans also lead to erosion of delta regions. Feedbacks between a changed land surface and the atmosphere may also be important. Irrigated land reduces temperature and increases humidity locally, and cloud amount and rainfall may be enhanced downstream. There is also the potential that synoptic-scale impacts, such as large-scale deforestation or irrigation, may influence the strength of the monsoon and character of rain systems.

Our projections of future climate and water resources will increasingly need to include anthropogenic interventions in land cover and freshwater systems. Management of these scarce resources, with changing demands and climate, requires a detailed understanding of the systems, and their impacts and feedbacks.

Exchanges with the iLEAPS community provided a number of new perspectives regarding the above issues; a good example is the interactions between air quality and irrigated regions. Many irrigated areas are low lying and densely populated and experience poor air quality, which can influence radiation and hence evaporation. Also high ozone levels will damage plants and influence photosynthesis and transpiration. In turn, nitrogen oxides released from fertilizers can interact with volatile organic compounds to produce additional pollution and aerosols. These issues are outside the immediate GEWEX interests but remain important research themes for iLEAPS and emphasize the need for a whole systems approach to future projections.

These and related issues will be the subject of a dedicated session, "Water Cycle over the Breadbaskets: Cities, Agriculture and Environment," at the 8th GEWEX Science Conference in Canada, 6-11 May 2018.

References

IPCC, 2013. Climate Change 2013. The Physical Science Basis. *Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324.

Pokhrel, Y.N., et al., 2012. Model estimates of sea-level change due to anthropogenic impacts on terrestrial water storage. *Nat. Geosci.*, 5, 389-392.

Quesada, B. et al, 2017. Reduction in monsoon rainfall in response to past and future land use and land cover changes. *Geophys. Res. Lett.*, 44, 1041-1050.

Taylor, C.M., et al., 2017. Frequency of extreme Sahelian storms tripled since 1982 in satellite observations. *Nature*, 544, 475-478.

4th Satellite Soil Moisture Validation and Application Workshop

TU Wien, Vienna, Austria
19–20 September 2017

Wolfgang Wagner[1], Thomas J. Jackson[2], John J. Qu[3], Richard de Jeu[4], Nemesio Rodriguez-Fernandez[5], Rolf Reichle[6], Luca Brocca[7] and Wouter Dorigo[1]

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The purpose of the Satellite Soil Moisture Validation and Application Workshop series is to discuss and reconcile methodological advances in the development, validation and application of global satellite soil moisture data. The workshops bring together satellite teams with validation experts and users to focus on the derivation, validation and exploration of soil moisture data from passive and active microwave satellite missions. These include but are not limited to the National Aeronautics and Space Administration (NASA) Soil Moisture Active Passive (SMAP) mission, the European Space Agency (ESA) Soil Moisture and Ocean Salinity (SMOS) mission, the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) Advanced Scatterometer (ASCAT) on board the series of MetOp satellites, the Japan Aerospace Exploration Agency (JAXA) Advanced Microwave Scanning Radiometer 2 (AMSR2) and the Synthetic Aperture Radar (SAR) on board the ESA Sentinel-1 satellites.

The fourth workshop in the series was jointly organized by the Vienna University of Technology (TU Wien), the U.S. Department of Agriculture (USDA), Vandersat, George Mason University and the Earth Observation Data Centre for Water Resources Monitoring (EODC). Co-sponsoring and support came from ESA, EUMETSAT, the Austrian Research Promotion Agency (FFG), the World Meteorological Organization (WMO), GEWEX, the Global Climate Observing System (GCOS), the Committee on Earth Observation Satellites (CEOS) and the Multidisciplinary Digital Publishing Institute (MDPI). More than 100 scientists from 22 countries participated, representing a large cross section of the soil moisture community. The workshop opened with an in memoriam tribute to Alexander Löw from the Ludwig Maximilian University in Munich, Germany, who had always been an active supporter of this workshop series. He led several international community projects such as the review of "Validation practices for satellite-based Earth observation data across communities," which was published only recently in the *Reviews of Geophysics*.

Many presentations at the workshop focused on the SMAP satellite that was launched less than three years ago on 31 January 2015. These presentations corroborated the very encouraging initial SMAP results presented at the last soil moisture workshop held in September 2016 in New York. This year's results confirmed that the SMAP brightness measurements are within specifications and the soil moisture retrievals meet the mission requirement of an unbiased root mean square error of 0.04 m^3m^3. Comparison of SMAP data with retrievals from other satellite (e.g., SMOS, ASCAT, AMSR2) and in situ measurements from around the world furthermore confirmed that the performance of the different soil moisture data products is variable in space and time, and that the best results can be achieved by combining observations from the different satellites and by assimilating the satellite observations into land surface modeling systems (see figure on next page).

In efforts to derive higher resolution soil moisture data products, Sentinel-1 SAR data have received the most attention. Sentinel-1 data are very attractive but are not easy to deal with due to the large data volume and the increased complexity of the processes when moving from the 20-50 km scale to 1 km or even to field scale. As a result, most studies have used Sentinel-1 for the downscaling of the coarser-resolution instruments (e.g., SMAP, SMOS, ASCAT, AMSR), rather than attempting a direct retrieval.

Satellite soil moisture data have been taken up by a wide variety of users (e.g., meteorologists, hydrologists, agricultural users); several real-world applications are benefiting from using and integrating such observations. At the workshop, it was shown that the assimilation of satellite soil moisture observations improves flood prediction, even in medium-sized basins (less than 500 km^2). Further evidence of the added value of satellite soil moisture data includes, among other benefits, the improvement of energy flux estimation through land-surface modeling, the advancement in the estimation of satellite precipitation and, recently, the detection and quantification of irrigation. However, it was observed at the workshop that additional effort is required to achieve a greater involvement of the user community. Specifically, better communication about limitations of the data is needed to avoid wrong usage (e.g., under frozen soils or in densely vegetated areas) and to inform them of the different satellite soil moisture products that are currently freely available. Capacity building is fundamental to globalizing societal applications of satellite soil moisture data sets and building consensus on key questions and recommendations.

The workshop concluded with a discussion in which the following two questions were addressed: (1) Is there a need for updating the GCOS accuracy requirements? and (2) What are the recommendations for future satellite soil moisture missions?

GCOS Accuracy Requirements for Soil Moisture

Soil moisture was endorsed by GCOS as an essential climate variable (ECV) in 2010. As a result, GCOS regularly assesses the observation capabilities for soil moisture (both the satellite and in situ components), identifies gaps in observational capabilities and formulates/updates observation requirements. Workshop participants were asked whether the observation requirements for surface soil moisture observations as presently

formulated in Annex 1 of the GCOS 2016 Implementation Plan (temporal sampling of 1 day, spatial resolution 1–25 km, accuracy of 0.04 m^3/m^{-3} and stability of 0.01 m^3/m^3/year) are still appropriate. The consensus was that these requirements are still adequate. However, workshop participants expressed the need for a clearer definition of these requirements. Furthermore, the workshop participants emphasized the need to consider variables that are closely related to soil moisture, such as vegetation optical depth, freeze/thaw, surface inundation and root-zone soil moisture, which is in line with the GCOS 2016 Implementation Plan.

Recommendation for an L-Band Follow-on Mission

As an introduction to this discussion topic, the initial concept for the Copernicus Space Component Evolution was presented. The European Commission identified monitoring greenhouse gases, polar regions and agriculture as the highest priorities based on an interim conclusion of user requirement analyses. These were followed by soil moisture together with other parameters, such as biodiversity and mining. The next generation of Sentinel-1 satellites could potentially include an L-band SAR system and low frequency radiometers (e.g., for L- and C-band).

The workshop participants welcomed data continuity for the C-band SAR on board Sentinel-1, as it has proven its value for delivering information at high spatial resolution. Although the absolute accuracy of Sentinel-1 soil moisture retrievals is at present still low, the measurements have been used to downscale the more accurate larger-scale soil moisture estimates from active and passive systems (i.e., ASCAT, AMSR2, SMOS and SMAP). While continuity for ASCAT and AMSR is foreseen, the participants were highly concerned regarding the long-term continuity of passive microwave L-band observations.

Therefore, it was strongly recommended to start activities defining a future L-band observation system based on the lessons learned from SMOS and SMAP. In addition, efforts will be made to keep L-band as a protected band for scientific applications and to detect out-of-band emissions so that regulatory measures can be taken.

Across missions and applications, the workshop participants agreed on the high value of representative and verified in situ measurements as a means for independent validation of the different satellite data products; the International Soil Moisture Network (ISMN) will be continued as the primary global database for harmonized and quality checked observations.

CCI Soil Moisture User Workshop

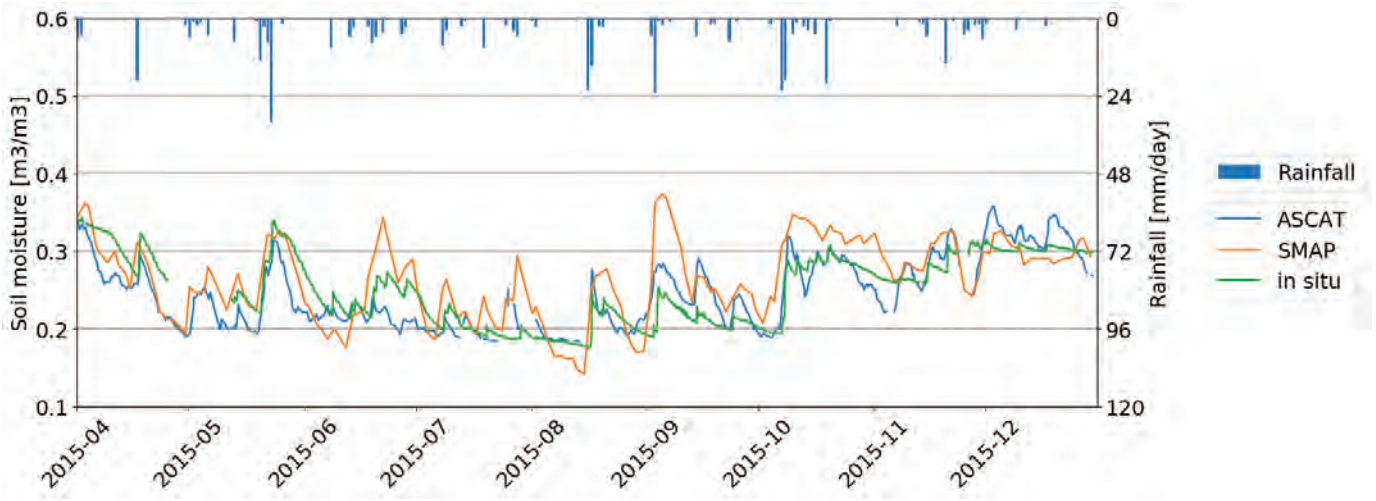
The soil moisture workshop was preceded by a one-day soil moisture user workshop organized within the framework of the ESA Climate Change Initiative (CCI) programme. The goal of this workshop was to bring together producers and users of the ESA CCI multi-sensor soil moisture product. Almost 80 scientists attended the workshop. One of the key messages uncovered by the discussions was that data consistency over time is one of the major requirements for a long-term data record like ESA CCI soil moisture. The user feedback provided important suggestions for potential future improvements (e.g., the use of an L-band climatology as a reference to which all other sensors shall be scaled) and the production of a root zone soil moisture product.

Next Workshop

The 5th Satellite Soil Moisture Validation and Application Workshop is scheduled for 24–25 October 2018 at George Mason University, Fairfax, Virginia USA. The plan is to focus the workshop on soil moisture applications.

Special Issue

Selected papers that expand on the workshop presentations will appear in the journal *Remote Sensing*, collected in a special issue entitled "Retrieval, Validation and Application of Satellite Soil Moisture Data." (*http://www.mdpi.com/journal/remotesensing/special_issues/soilmoisture*).



Comparison of SMAP L3 and ASCAT H109 soil moisture retrievals to in situ measurements from the Hydrological Open Air Laboratory (HOAL) site in Petzenkirchen, Austria.

GEWEX Data and Assessments Panel (GDAP) Meeting

Boulder, Colorado, USA
9–12 October 2017

Rémy Roca[1] and Tristan L'Ecuyer[2]
[1]Laboratoire d'Etudes en Geophysique et Oceanographie Spatiales, LEGOS, Toulouse, France; [2]University of Wisconsin-Madison, Madison, Wisconsin, USA

The annual meeting of GDAP was hosted by Kevin Trenberth at the Mesa Laboratory of the National Center for Atmospheric Research. The meeting began with a special one-day workshop to coordinate the GEWEX and Climate and Ocean Variability, Predictability and Change (CLIVAR) research focus on planetary heat balance and ocean heat storage (CONCEPT-HEAT) activities centered upon documenting the Earth's energy imbalance. The main goals of the GDAP meeting were to: (1) obtain updates on all GDAP-sponsored ground sites [e.g., Global Precipitation Climatology Centre (GPCC) and Baseline Surface Radiation Network (BSRN)] and data sets [e.g., Surface Radiation Budget (SRB), Global Precipitation Climatology Project (GPCP), SeaFlux and LandFlux]; (2) establish plans for completing the currently open aerosol and cloud assessments; (3) re-scope the precipitation assessment; (4) discuss progress toward the GEWEX integrated data product (5) initiate a new paradigm of integrated budget closure assessments; and (6) establish GDAP's role in supporting crosscutting GEWEX activities like the Process Evaluation Study (PROES). Discussions focused on defining additional goals and directions for GDAP under the new leadership of its co-chairs, Rémy Roca and Tristan L'Ecuyer.

CONCEPT-HEAT Meeting

The joint meeting between GDAP and CLIVAR's CONCEPT-HEAT working group led to a better understanding of the different perspectives of these two WCRP communities regarding the important topic of quantifying the Earth's energy imbalance (EEI), which is the most fundamental driver of climate change. Quantifying global EEI and its regional and temporal variations requires a coordinated effort to integrate the best available observational data sets using modern methodologies. CONCEPT-HEAT, GDAP and the sea level community have all made progress toward this goal. Kevin Trenberth, Graeme Stephens and Detlef Stammer provided updates on each group's activities. CONCEPT-HEAT efforts have centered on establishing best estimates of changes in global ocean heat content (OHC), establishing consistency between OHC and top-of-atmosphere (TOA) radiation measurements and mapping air-sea fluxes as a residual using atmospheric and oceanic reanalyses. GEWEX integrative EEI activities have advanced primarily through GDAP, and specifically, the new Integrated Product. For more than three decades, GDAP (formerly the GEWEX Radiation Panel, GRP) has supported atmospheric and surface flux data sets and assessed their accuracy, and these activities are transitioning into fully integrated energy and water cycle assessments. The CLIVAR-sponsored sea-level budget initiative is addressing the specific problem of improved estimation of changes in OHC through analogous budget approaches. Benoit Meyssignac and Steve Nerem presented encouraging results from an effort to combine surface altimetry (e.g., Jason), terrestrial water storage (e.g., Gravity Recovery and Climate Experiment, GRACE) and in situ observations (e.g., Argo) to derive an integrated picture of the linkages between sea level change and EEI. Meyssignac emphasized the the associated uncertainties (see figure on next page).

Results presented by Carol Anne Clayson, Mathias Hauser, and Isabel Trigo reflect the progress toward establishing global estimates of land and ocean heat and moisture fluxes, and also highlighted the need to reduce structural uncertainties in these data sets. New variational methodologies that blend gridded flux observations with transport constraints show promise for advancing estimates of ocean basin-scale energy imbalances with associated uncertainty estimates. However, some key open questions remain that are particularly germane to GDAP objectives: *how do we move beyond using spreads between products as measures of uncertainty? What accuracy should the new integrated EEI activities be striving for? And what spatial and temporal analysis scales are realistically supported by current data sets?* These questions are, in part, motivated by the target audience for new EEI estimates. Andrew Gettelman pointed out the value of EEI and ocean-atmosphere heat exchange constraints, noting that many climate models still exhibit imbalances in TOA radiation of 2 Wm^{-2} or more. Bill Frey provided additional motivation for quantifying regional EEI and ocean-atmosphere exchanges by observing that models suggest that ocean heat uptake at mid-latitudes may exert a strong buffer reducing the influence of cloud feedbacks on climate sensitivity. Accurate estimates of EEI on regional scales may enable decadal-scale prediction. Steve Yeager suggested that the Community Earth System Model (CESM) has significant skill in hindcasts of variations of upper ocean heat content.

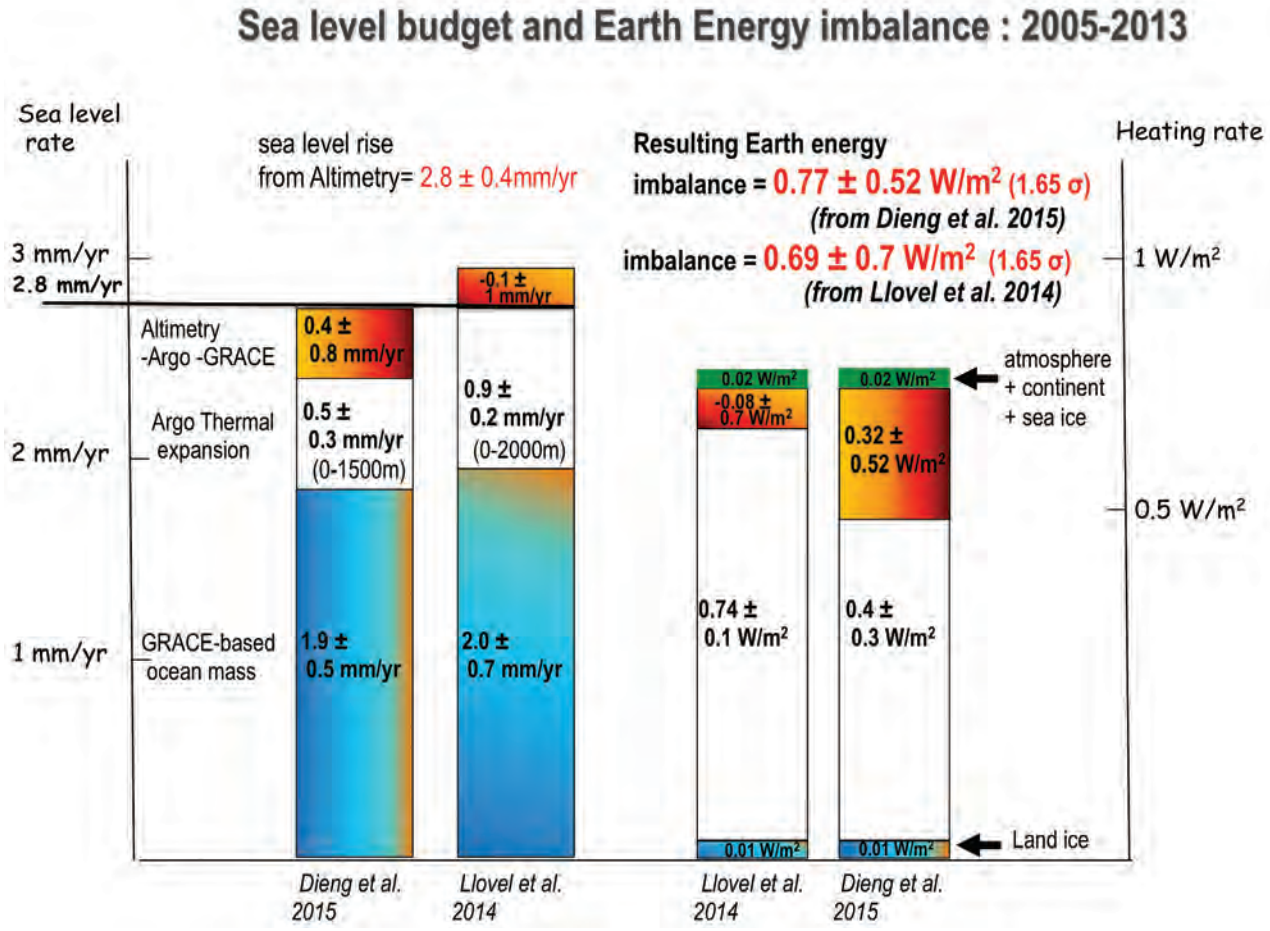
In addition to articulating support for focused EEI activities centering on integrating satellite and in situ observations, a key outcome of this one-day workshop was the need for a comprehensive assessment, or intercomparison, of methods for inferring EEI. A targeted effort to build upon recent approaches for objectively integrating distinct estimates of TOA radiation, atmospheric and oceanic mass and heat transports, air-sea fluxes, direct and indirect ocean heat content analyses and estimates of surface ice mass, heat content and water storage was also recommended. The consensus was to have a joint CLIVAR-GEWEX EEI workshop and it was suggested that this workshop be held in Toulouse, France, in late 2018. The goal of this open 3.5-day workshop would be to foster collaboration between the communities in WCRP to work toward an integrated view of EEI. The workshop would include invited keynote speakers and a lot of time for discussion. Four session topics were proposed: (1) coordinated assessment of global EEI and its components, (2) Regional EEI and transports, (3) Observational needs and prediction and (4) Cross-WCRP interactions on EEI. A steering committee

will be identified shortly composed of individuals representing CONCEPT-HEAT, CLIVAR and GEWEX along with additional representation from the Climate and Cryosphere (CliC) Project and the ocean reanalysis/modeling community.

Main GDAP Meeting

Rémy Roca opened the GDAP meeting on Tuesday by noting that GDAP leadership officially transitioned from outgoing co-chairs Jörg Schultz and Matthew McCabe to Rémy Roca and Tristan L'Ecuyer last December. In the nine months that followed, progress has been made toward each of GDAP's core activities, including: (1) sponsoring production and analysis of several key energy and water cycle data sets from satellites [e.g., International Satellite Cloud Climatology Project (ISCCP), GPCP, SeaFlux, SRB]; (2) sponsoring and overseeing assessments of these and other community data sets to improve uncertainty estimates; (3) sponsoring ground-based networks including BSRN and GPCC; (4) facilitating data access by scientific user communities; (5) acting as an interface between GEWEX activities and data sets [e.g., PROES, the GEWEX Aerosol and Precipitation (GAP) assessment, GASS]; (6) representing GEWEX at WCRP, WMO and other meetings and (7) reporting and responding to the GEWEX Scientific Steering Group (SSG).

Rémy Roca reported on GDAP activities to the GEWEX SSG in February 2017. The water vapor assessment report was well received but there was discussion of expanding the scope of the precipitation assessment. This is now underway and the International Precipitation Working Group (IPWG) and NASA Precipitation Measurement Missions (PMM) communities have been engaged. The SSG also suggested including land



Results from two different studies (Llovel et al., 2014 and Dieng et al., 2015) are shown where the Earth energy imbalance (EEI) was measured from space with the sea level budget approach for 2005–2013. Satellite altimetry provides estimates of the global mean sea level rise (GMSL), which is due to ocean thermal expansion and ocean mass change. The GRACE mission provides estimates of the global ocean mass (GOM) change that is primarily a result of land ice melt. GRACE data indicate a GOM change of about 2 mm/yr which corresponds to a heat gain by the cryosphere of about 0.01 Wm^{-2} over 2005–2013. The residual (GMSL−GOM) provides estimates of the thermal expansion of the ocean and is directly related to change in the ocean heat content (OHC). For 2005–2013, the residual from satellite altimetry minus GRACE indicates a total thermal expansion of about 0.8 mm/yr which corresponds to an OHC of about 0.7 Wm^{-2}. When added to the heat gain by the atmosphere, the continent and the sea ice, it gives a ***total Earth energy imbalance of 0.73±0.55 Wm^{-2} at the 90% confidence level*** *(1.65 sigma assuming a gaussian distribution). This estimate of OHC (and the associated EEI) has the advantage of covering the entire ocean from -82°S to +82°S. It is also consistent with the Argo-based estimate of OHC of the top 2000 m of the ocean (within the uncertainty).*

Participants at the GDAP Meeting.

surface temperature (LST) and possibly fluorescence as GDAP variables. Tristan L'Ecuyer represented GDAP at the 2nd GAP workshop, which was held in Oxford, UK. A primary outcome of that meeting was the need for metrics to evaluate aerosol influences on precipitation in global models and that GDAP should play an advisory role in establishing these. L'Ecuyer also participated in the Upper Tropospheric Cloud-Convection (UTCC) PROES meeting in New York, where GEWEX cloud, radiation and precipitation data sets are being used to study convection. Both Tristan and Rémy participated in the joint GEWEX/CONCEPT-HEAT Workshop prior to this GDAP meeting. GDAP will continue to maintain close connections to the WCRP Data Advisory Council (WDAC) and Observations for Model Intercomparisons Project (Obs4MIP) groups in an advisory capacity.

Global energy and water cycle data sets continue to be refined. New versions of several (e.g., SRB Release-4.0 and SeaFlux V2.0) have either been released or are in final stages of evaluation. The water vapor assessment report has been submitted and is under review. The next GEWEX water Vapor Assessment (G-VAP) meeting will take place at the University of Leicester, UK on 25-26 October 2017. An initial assessment of precipitation climatologies and seasonal cycles separated into land and ocean regions has also been completed by Hiro Masunaga. A more comprehensive assessment that includes sampling errors, examines regime-dependent differences and addresses high latitude and orographic precipitation and the needs of specific applications is now being scoped with inputs from the IPWG and PMM communities. Alexander Gruber presented an update on the soil moisture assessment and Claudia Stubenrauch outlined a timeline for the updated cloud assessment. The deadline for submitting new data sets to the updated cloud assessment is March 2018 and the analysis will be completed by the end of summer. This work complements ongoing activities within the International Cloud Working Group (led by Mike Foster and Martin Stengel). The aerosol assessment needs to be resurrected although there has been some progress in this by Stefan Kinne under the AeroCom Project and a new Max Planck Institute Aerosol Climatology (MACv2.0) data set is available.

Good progress has been made on the **GEWEX Integrated data set**. One year of the complete 1-degree, 3-hourly product (January-December 2017) is available for download at: *ftp://rain.atmos.colostate.edu/ftp/pub/GEWEX_IP/pbrown/GEWEX_IP/2007/*. This data set is being used to examine water cycle closure at the ocean basin scale, consistent with the concept of closure-based assessments envisioned for GDAP by former chair, Chris Kummerow. Such closure studies are part of a broader reshaping of GDAP objectives and activities to reflect the new directions in satellite and climate science. While assessment of individual parameters will continue, *some focus is shifting toward integrated assessments of global data projects that apply energy and water cycle closure constraints as an integrated measure of systematic errors in data sets*. This effort, coupled with a renewed focus on defining application-centric uncertainties appropriate to specific time and space scales, will help GDAP better serve the science community. Prior assessments, new objective optimization approaches and the GEWEX Global Integrated Product that bring together the separate parameter centric products at the highest feasible space-time resolution for global process studies will play a key role in this activity. New global data products should continue to be focused on improving the long-time-record quality of the products so that they can be used more confidently for climate monitoring studies. This activity should now make plans for the long-term stewardship of these products, including continuing to lead efforts to convert research analyses to climate operations.

The final day of the meeting focused on reassessing GDAP's core mission, discussing open business and setting new directions. A consensus regarding GDAP assessment activities is evolving along having more integrated themes that seek tests of water cycle and energy balance closure and aim to establish consistency between data sets (e.g., between surface radiative fluxes and the aerosols, land surface temperature and cloud fields used to generate them). This is viewed as a positive step toward meeting the evolving needs of the community and has triggered the suggestion that GDAP undergo a small name change to the **GEWEX Data and Analysis Panel**. GDAP will continue to support the ongoing set of assessment activities to their logical conclusion (submission of a formal report) and

would also initiate several new integrated assessments leading to a more complete description of the weather-to-climate scale variations of the global energy and water cycle. GDAP is planning to have an active role in organizing related sessions at the upcoming GEWEX Science Conference in May 2018 and will continue to support ground-based networks like BSRN and GPCC. BSRN continues to serve as the reference for surface radiation budget estimates. Stability is very good but establishing absolute calibration of fluxes is still an ongoing activity. The next BRSN scientific review and workshop will take place in Boulder, Colorado on 20-26 July 2018.

The top priorities for completing ongoing assessments in the coming year include: completing the cloud assessment update, expanding the scope of the precipitation assessment, resurrecting and completing the aerosol assessment and initiating a new radiative heating rate profile assessment. GDAP may also recommend a formal soil moisture assessment or endorse creating an official GEWEX global soil moisture product. With these continuing activities as a foundation, future emphasis will be focused on integrated assessments to constrain atmosphere and oceanic transports of energy and water. It is envisioned that future reprocessing of current global products will benefit from such information by increasing the physical consistency of the products and reducing spurious variations in the long-term record. GDAP will also leverage the results of these integrated assessments to engage space agencies and other international stakeholders to refine global climate observing systems and associated climate data records.

To stimulate these integrated assessments, three initial activities are being discussed. The first involves applying merged data sets like the GEWEX Integrated Product (which will be released to the community in the coming months and expanded to include more years) to test energy and water budget closure on regional and global scales. It is anticipated that this effort will provide independent evidence for regime-dependent structural errors in flux products that may ultimately lead to their improvement. This activity necessarily requires more deliberate interaction with general circulation modeling groups. To that end, future membership of GDAP will include representatives from the modeling communities.

Through the integrated assessment effort, GDAP will also directly contribute to complementary CONCEPT-HEAT studies that are directed toward quantifying global and regional EEI and establishing consistency between TOA fluxes and ocean heat content. To foster this activity, a representative from the ocean heat content or ocean reanalysis community may be added to GDAP. A third application of integrated assessments may center on re-scoping the LandFlux activity to include a more comprehensive assessment of land surface fluxes in the context of land surface temperature and ground water storage. GDAP may seek to incorporate global LST into its product suite as part of this activity. GDAP may also pursue adding a member with broad experience in land surface processes/flux in the future. To foster closer ties with the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Program community in future assessments, GDAP may also consider basing a land surface closure assessment around the ARM Southern Great Plains site.

The new vision of GDAP supporting global energy and water-related scientific investigations through integrated assessments warrants two additional activities. First, Roca and L'Ecuyer will initiate a revamping of the GDAP web pages to more accurately reflect its role in supporting other GDAP panels, PROES and broader scientific collaborations. This will include organizing people involved with GDAP into three groups: (1) core members, (2) project and assessment leads (PALS) and (3) science and analysis leads (SALS). The second activity will be an effort to engage all of these groups in compiling a set of "General Guidelines for Scientific Assessments" that will summarize GDAP's vision of best practices for conducting assessments that maximize value to the scientific community. This report will integrate existing best practice documents from other WCRP groups but will cover a much broader focus that includes initial scoping meetings, methods for framing assessments around science questions, identifying reviewers, disseminating reports and engaging stakeholders including space agencies and government groups.

A number of additional programmatic recommendations were raised at the meeting. GDAP strongly endorses the proposed creation of an ISCCP-NG product to utilize new geostationary and polar orbiting cloud information and coordinate efforts to inter-calibrate sensors. GDAP emphasizes the need for supporting comprehensive assessments of individual fluxes and integrated assessments of energy and water cycle closure on global to regional scales. GDAP recommends a review of current methods for transferring global data products to operational centers and the development of explicit succession plans for maintaining required expertise. The complete report of the GDAP meeting will be available at: *https://www.gewex.org/panels/gewex-data-and-assessments-panel/meetings-and-reports/*.

New member Isabel Trigo will host the next GDAP meeting in Portugal the last week of November 2018. GDAP will have a significant presence at the upcoming 8th GEWEX Science Conference in Canmore, Alberta, Canada in May 2018. Session 9, Energy Budget and Water Cycle Closure and Assessment, will focus on contributions that synthesize multiple energy and water variables derived from observations (in situ, satellite), reanalyses or climate models to examine energy and water cycle closure on regional through global scales. To submit an abstract and register, please visit the conference website at: *https://www.gewexevents.org/events/2018conference/*.

References

Ablain, M., et al., 2015. Improved sea level record over the satellite altimetry era (1993–2010) from the Climate Change Initiative project. *Ocean Sci*., 11, 67-82, doi:10.5194/os-11-67-2015.

Dieng, H.B., A. Cazenave, K.V. Schuckmann, M. Ablain and B. Meyssignac, 2015. Sea level budget over 2005-2013: Missing contributions and data errors. *Ocean Sci*. 11, 789-802, doi: 10.5194/os-11-789-2015.

Llovel, W., J.K. Willis, F.W. Landerer and I. Fukumori, 2014. Deep-ocean contribution to sea level and energy budget not detectable over the past decade, *Nat. Clim. Change* 4, 1031–1035 (2014), doi:10.1038/nclimate2387.

Joint GEWEX Hydroclimatology Panel and Third Pole Experiment Workshop

Kathmandu, Nepal
17–19 October 2017

Joan Cuxart, GHP Co-Chair
Department of Physics, University of the Balearic Islands, Palma, Majorca, Spain

GEWEX and Dr. Ailikun, Director of the International Programme Office of the Third Pole Experiment (TPE), organized the Joint GHP-TPE Workshop with local support from the Tribhuvan University of Kathmandu. TPE and Nepali scientists presented their research on the energy and water cycles of the Tibetan Plateau. The GEWEX Hydroclimatology Panel (GHP) members and representatives communicated the status of their Regional Hydroclimate Projects (RHPs), Crosscuting Projects (CCs) and Data Centers related to this region. The joint workshop provided TPE, Nepali scientists and GHP the opportunity to strengthen links between related research.

The status of ongoing activities was presented at the GHP meeting, which took place in three afternoon sessions. The Hydrological cycle in the Mediterranean Experiment (HyMeX) and the Changing Cold Regions Network (CCRN) RHPs, respectively studying the Mediterranean Basin and cold regions in Canada, are steadily progressing and generating new actions for the coming years. Baltic Earth continues the research started by The Baltic Sea Experiment (BALTEX) two decades ago and has applied to GHP to be a full, working RHP. Two RHPs continue their development as initiating RHPs, the Australian Energy and Water Exchanges (OzEWEX) Project and the Hydrology of Lake Victoria Basin (HyVic) in Eastern Africa. PannEx, the prospective RHP centered in the Pannonian Basin in Europe, presented its white book and science and implementation plan for approval and has applied for initiating RHP status. Three GHP Crosscutting Projects, the International Network for Alpine Catchment Hydrology (INARCH) on mountain hydrology, the Intelligent use of climate models for adaptation to non-Stationary hydrological Extremes (INTENSE) program on sub-daily precipitation and Precipitation Near 0ºC in cold/shoulder environments, show significant advances. Current activities in the global Data Centers were presented for the Global Runoff Data Centre (GRDC), the International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE) and the Global Precipitation Climatology Centre (GPCC).

New initiatives were proposed, including a joint TPE/GEWEX crosscutting action on water security in the Third Pole. A study on the water cycle in the Andean region of South America may take the form of an RHP in the near future. A new CC related to water management in models will explore anthropic actions in numerical models.

The increase in the networking activities by the RHPs was positively received; however, it was noted that such activities should not delay the obligation of the RHPs to fulfill and report on their progress towards addressing the GEWEX Science Questions and detailing the regional aspects of each RHP. CCs that are on their third and final year were encouraged to apply to GHP for a continuation. More outreach activities related to GEWEX activities are encouraged, especially those attracting young researchers through workshops and special projects.

In addition, other cohesive ventures between the GHP activities were suggested, such as organizing RHP events, increasing the organization of Coordinated Regional Climate Downscaling Experiment (CORDEX) activities among RHPs and promoting GHP undertakings related to the United Nations Sustainable Development Goals or that result in peer reviewed publications.

Conclusions from the meeting will be presented to the GEWEX Scientific Steering Group at its 30th session in early 2018.

Participants at the Joint GEWEX/TPE Workshop.

Joint YESS-YHS Early Career Researcher (ECR) Workshop 2018

Towards Regional Information to Improve Our Understanding on Weather and Climate Extreme Events

3-5 May 2018 | Canmore, Alberta, Canada

Application Deadline: 18 December 2017

The Young Earth System Scientists (YESS, *http://www.yess-community.org/*) and Young Hydrologic Society (YHS, *https://younghs.com/*) are holding a Joint YESS-YHS Early Career Researcher (ECR) Workshop prior to the 2018 GEWEX Science Conference. The 3-day workshop will bring together early career researchers and students to have an in-depth, interdisciplinary discussion about enhancing the generation of regional information on different spatial and temporal scales, and on the utility of that information for users, decision makers and other stakeholders. A special emphasis will be placed on how weather and climate extreme events change and how new data sources and modeling approaches can advance our understanding of and adaptation to such changes. The workshop will further serve to evaluate what the early career communities have achieved in recent years and how they can enhance their interactions, in addition to fostering collaborations with other early career networks.

Attendance is limited to 40 people. The selection process will account for gender, geography, scientific background and merit. The application materials and process are described at *https://www.gewexevents.org/events/2018conference/ecr/workshop-application/*.

GEWEX/WCRP Calendar

For the complete Calendar, see: http://www.gewex.org/events/

11–15 December 2017—AGU Fall Meeting—New Orleans, LA, USA

7–11 January 2018—98th AMS Annual Meeting—Austin, TX, USA

22–31 January 2018—2nd WCRP Summer School on Climate Model Development—Cachoeira Paulista, SP, Brazil

29 January–2 February 2018—30th Session of the GEWEX Scientific Steering Group—Washington, DC, USA

5–9 February 2018—AMOS-International Conference on Southern Hemisphere Meteorology and Oceanography—Sydney, Australia

6–8 February 2018—HEPEX Workshop on "Breaking the Barriers"—Melbourne, Victoria, Australia

8–9 February 2018—3rd International Network for Alpine Research Catchment Hydrology (INARCH) Workshop—Zugspitze, Germany

26 February–2 March 2018—2nd GEWEX Pan-Global Atmospheric System Studies (GASS) Conference—Lorne, VIC, Australia

5–7 March 2018—Cities and Climate Change Science Conference—Edmonton, Canada

14–19 March 2018—International Symposium on Cryosphere and Biosphere—Kyoto, Japan

8–13 April 2018—European Geosciences Union General Assembly—Vienna, Austria

16–20 April 2018—39th WCRP Joint Steering Committtee Meeting—TBD, China

17–27 April 2018—Polar Prediction School 2018—Abisko, Sweden

3–5 May 2018—Joint YESS-YHS Early Career Research Workshop—Canmore, Alberta, Canada

6–11 May 2018—8th GEWEX Science Conference: Extremes and Water on the Edge—Canmore, Alberta, Canada

29 May–2 June 2018—11th HyMeX Workshop—Lecce, Italy

11–15 June 2018—2nd Baltic Earth Conference—Helsingoer, Denmark

GEWEX NEWS

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