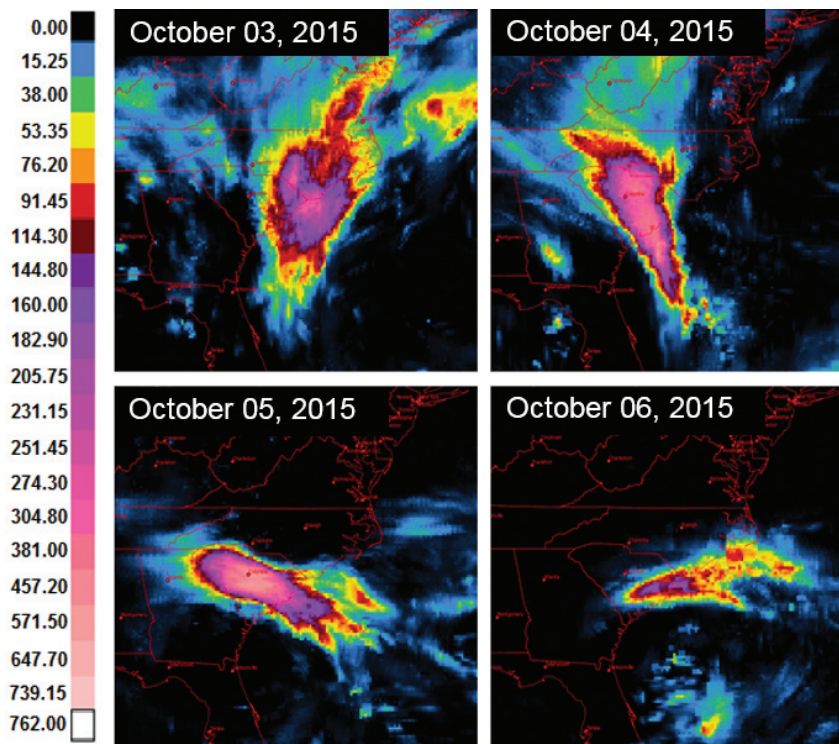


Using Soil Moisture Active Passive Satellite and Global Precipitation Measurement Mission Measurements to Map the 2015 South Carolina Flood



Daily accumulated rainfall (mm) from the GPM multi-satellite product (IMERG) Version 3 for the heavy rainfall days of 3–6 October 2015 over the Southeastern United States. The “early” IMERG estimate, five hours after observation time, provides a basis for quickly estimating extreme precipitation events and the consequent flooding and landslides over most of the globe (currently 60°N-S), while longer-latency products incorporate more data, including monthly gauge analyses in the post-real-time “final” research product. As demonstrated here, multi-satellite products provide a unified view of precipitation over both land and ocean, which is not possible from surface-based observations, even retrospectively. Figure 2 from article by V. Lakshmi et al. on page 6.

Winners of the Early Career Researcher Video Competition (Page 5)

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Commentary

Water for the Food Baskets of the World

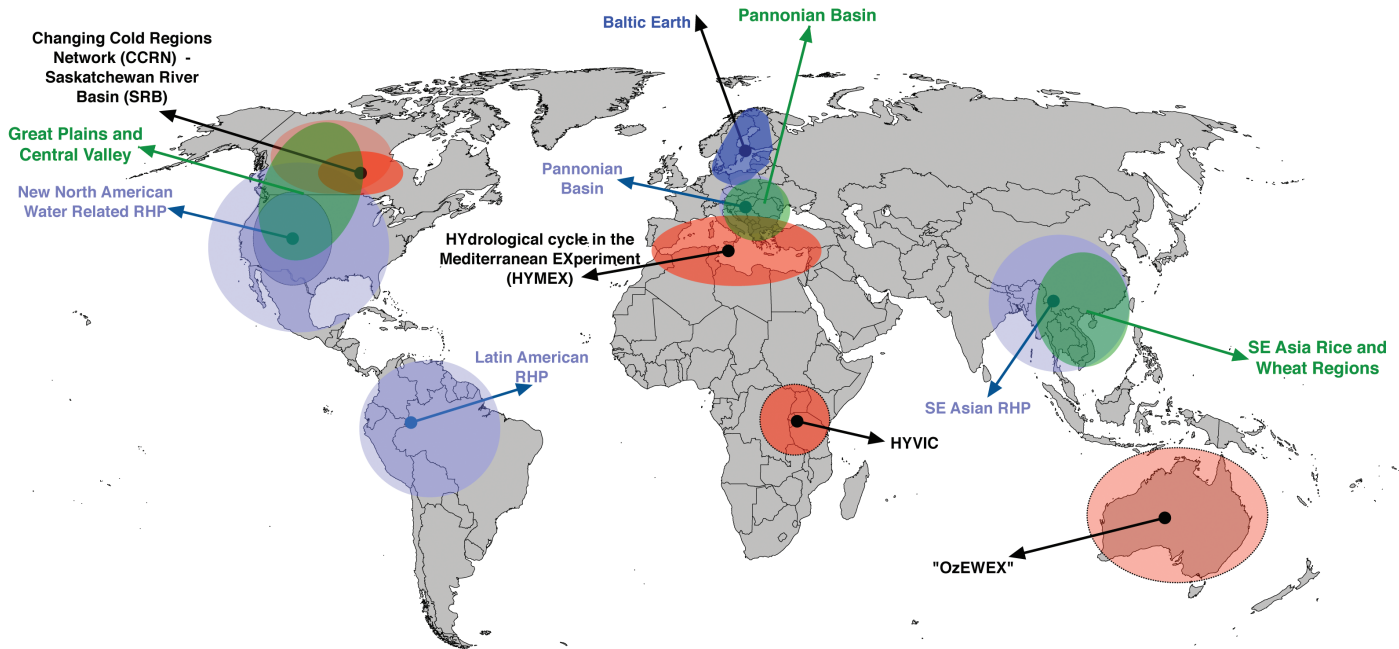
Peter van Oevelen
 Director, International GEWEX Project Office

At the recent meeting of the World Climate Research Programme’s Joint Scientific Committee, GEWEX presented an implementation strategy for the WCRP Grand Challenge on Water Availability. This Grand Challenge, which is called “Water for the Food Baskets of the World,” is framed by one overarching science question: *How will a warming world affect the available fresh water resources globally, the human interactions with these water resources, as well as their value to society and how does this translate specifically to the food basket regions of the world?* This question is not only about water supply and demand, but also changing societal and environmental responses. For example, variations in water availability can lead to changes in surface and soil characteristics and different agricultural regime practices, which may require solutions such as deeper wells and desalinization plants. Within the context of WCRP, the focus will be on the geophysical and anthropogenic influences on water availability. As the lead on this Grand Challenge, GEWEX will develop links to many other activities within and outside the realm of WCRP to properly address it. For GEWEX specifically, this Challenge offers several exciting directions and will provide an overarching theme for many of its regional activities. It also provides a strong rationale for including anthropogenic influences on water

and energy cycle processes, referred to in our research as the “human dimension,” and incorporates previously-mentioned aspects such as irrigation, water management and water extraction. The modeling of these influences requires different types of data, some outside our normal purview. For example, data on water usage and water management are often difficult to obtain, and creative solutions will be needed to acquire these directly or indirectly through indicators. The regions to be addressed initially are the Central Valley and Great Plains of North America, the Pannonian Basin in Europe, and the wheat- and rice-producing regions of Eastern Asia, China in particular. Each of these regions has distinctly different hydrological regimes and associated issues, providing a unique opportunity to study the effect of global climatic change on water-related phenomena.

This Grand Challenge connects various GEWEX regional activities, especially the Regional Hydroclimate Projects (RHPs; see figure below). It also presents a great opportunity and theme for developing new research activities within the United States and could provide a framework for a new North American-based RHP. To that purpose, we have organized a meeting in Columbia, Maryland on 3–5 May to explore possibilities and rally the community to develop collaborative ideas.

In the next few years, GEWEX plans to organize numerous workshops and conference sessions in support of this Grand Challenge. This is in addition to the many other activities we normally undertake and support as central to our project. The WCRP Grand Challenges are focused, time-limited efforts that conclude in 5–10 years. On the GEWEX website events calendar you can find an overview of these meetings along with links to logistical and registration information.



Current GEWEX Regional Hydroclimate Projects (in red), some prospective RHPs (in blue), and the Food Basket Regions on which the WCRP Grand Challenge will focus initially (in green).

Young Earth System Scientists (YESS) — Fostering a Global Research Community

Gaby Langendijk and YESS Outreach Working Group
World Climate Research Programme, Geneva, Switzerland

Launched in 2010 by a group of students in Hamburg, Germany, YESS is an international network of multidisciplinary early career Earth system scientists studying and working in fields ranging from climate to weather to water-related applications. Since its inception, YESS has given a collective voice and provided leverage to Early Career Scientists (ECS) while promoting exchanges across multiple disciplines related to Earth system sciences. YESS is supported by the three research arms of the World Meteorological Organization: the World Climate Research Programme, the World Weather Research Programme and the Global Atmosphere Watch Programme. This backing enabled the YESS Council to meet for the first time at the Earth System Science Frontiers Workshop held in October 2015, hosted by Deutscher Wetterdienst in Offenbach, Germany (<http://public.wmo.int/en/resources/bulletin/young-earth-system-scientists-yess-community>). Key topics discussed at the workshop and summarized in a white paper included seamless Earth system prediction, communication, user-driven science and interdisciplinarity. Participants also identified the needs of the ECS network that are required to tackle these science challenges and worked to develop an implementation strategy for expanding the YESS network internationally.

As an outcome of its newly developed structure, the first election of the YESS Executive Committee was held in March 2016. Seven committee members were selected to be responsible for guiding YESS activities and serve as points of contact within the YESS community and with its external partners. In addition, the first regional representatives, who are responsible for the growth of YESS in their area and for addressing special regional questions and tasks, were chosen.

YESS has also collected the opinions of young scientists and developed an open statement concerning the mass cuts of 350 climate scientists at Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO). The statement warned how detrimental these dismissals will be to the next generation of Earth system scientists.

YESS also maintains an active presence at conferences and research institutions around the world. A YESS Information Day was organized in partnership with the doctoral school of the Tunisia Polytechnic School. YESS was present at the April meeting of the European Geosciences Union in Vienna, and will be at the CORDEX International Conference on Regional Climate in Stockholm in May and at the CLIVAR Open Science Conference and Early Career Scientists Symposium in Qindao, China, during September.

If you are a Ph.D. student or Postdoc and are interested in joining the YESS community, please email us at contact@yess-community.org.

UNESCO-IHP: Addressing Societal Resilience to Climate Change Through International Scientific Cooperation

Anil Mishra, Abou Amani, Blanca Jiménez-Cisneros
and Bárbara Ávila

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Water resources are under increasingly severe pressure from climate change and other global drivers. Climate change alters rainfall patterns, soil moisture, humidity, glacier-mass balance and river flow, and also causes changes to the quality of water and to aquifer recharge resources. At the same time, floods and droughts are rising in frequency and intensity while the population is becoming more exposed and vulnerable. Over the next 40 years, it is estimated that 800,000 new residents will move to cities around the world every week (UNESCO-IHP, 2014). Population growth and rapid urbanization will create further pressures on water resources and will have a tremendous impact on the environment.

The International Hydrological Programme (IHP) is the only intergovernmental program of the United Nations system devoted to water research, water resources management and education and capacity building. Since its inception in 1975, IHP has evolved from an internationally coordinated hydrological research program into an encompassing, holistic program to facilitate education and capacity building, and enhance water resources management and governance. IHP facilitates a transdisciplinary and integrated approach to watershed and aquifer management, which incorporates the social dimension of water resources, and promotes and develops international research in hydrological and freshwater sciences. IHP is implemented in 8-year programmatic time intervals or phases and the eighth phase (IHP-VIII) is now being implemented for the period of 2014–2021.

The definition of Water Security adopted by the UNESCO-IHP Intergovernmental Council is “the capacity of a population to safeguard access to adequate quantities of water of acceptable quality for sustaining human and ecosystem health on a watershed basis, and to ensure efficient protection of life and property against water related hazards (floods, landslides, land subsidence and droughts).” Given population growth, degradation of water quality, the growing impact of floods and droughts and other hydrological effects of global change, water security is an increasing concern. Consequently, the overarching focus of the eighth phase of IHP is encompassed in its title, “Water security: Responses to local, regional and global challenges.” To deal with the complex, rapid environmental and demographical changes, holistic, multidisciplinary and environmentally sound approaches to water resources management and protection policy are being sought in line with the Paris Climate Change agreement and with the international 2030 development agenda.

IHP plays a vital role in providing a scientific knowledge base for policy advice to manage and cope with challenges to water resources, including disasters and floods, and to increase the resilience of natural and human systems with an emphasis on vulnerable communities. Through its activities enhancing the science policy interface, promoting international cooperation to mobilize research and supporting human and technical capacity building, IHP contributes to the implementation of the United Nations goals and commitments, such as the Sustainable Development Goals.

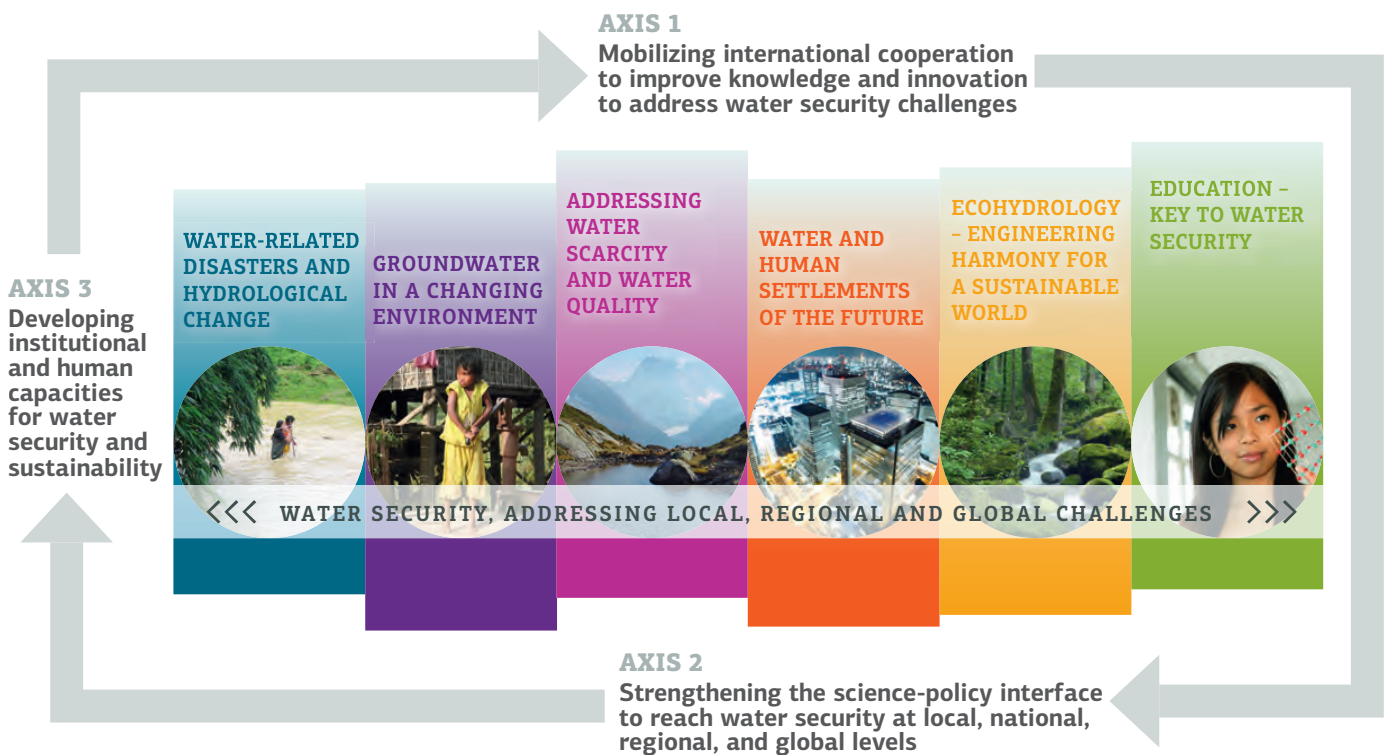
Responding to the priorities and needs of the Member States, IHP-VIII focuses on six thematic areas to assist them in their endeavor to optimize water management and security. These thematic areas are shown in the figure below.

With the intensification of the hydrological cycle due to climate change, it is crucial for society to apply a paradigm shift to better address consequences related to extreme events. Moving from a crisis management approach (e.g., impact assessment, response, recovery and reconstruction) to a risk management approach (e.g., mitigation, preparedness, prediction and early warning) can lead to increased coping capacity and resilience.

This change will require evidence-based decision making using a sound understanding of the hazard, the vulnerability and the coping capacity of the population. Through its vari-

ous programs, such as the International Flood Initiative (IFI), International Drought Initiative (IDI) and the Global Network on Water and Development Information for Arid Lands (G-WADI), UNESCO-IHP has been promoting scientific cooperation for improving knowledge on hazards and vulnerability with the development of early warning and monitoring tools, methodologies and capacity.

IHP has been collaborating with the Center of Hydrometeorology and Remote Sensing (CHRS) at the University of California-Irvine in the development of tools that contribute to reducing climate change effects on water resources. These tools include G-WADI GeoServer precipitation maps, the Drought/Floods Monitoring and forecast system. Furthermore, the collaboration provides real-time satellite precipitation data within the G-WADI framework. The G-WADI Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks Cloud Classification System (PERSIANN-CCS) GeoServer offers graphical tools and a data service to help in emergency planning and management for natural disasters related to hydrological processes. The Namibia Hydrological Services (NHS) uses G-WADI GeoServer data to prepare a daily flood/hydrological drought bulletin with up-to-date information on flood and drought conditions for local communities. This information assists the NHS in making more accurate judgments on future water supply for multiple uses, and provides early warning for



Building synergies to enhance water resources management and support Member States as they build resilience by developing and promoting the use of data tools and methodologies.

floods and droughts in areas located in national and trans-boundary river basins.

IHP in collaboration with Princeton University also supported the development of a drought/floods monitoring and forecast system that has been deployed and used in West and Eastern Africa by the Centre Regional de Formation et d'Application en Agrométéorologie et Hydrologie Opérationnelle (AGRHYMET) and the Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC) to complement their current monitoring system to help decision makers anticipate and take appropriate actions depending on the evolution of agro-hydro-meteorological situations. This system is in the process of deployment in the Southern Africa region.

More recently, IHP and the World Glacier Monitoring Service (WGMS) launched the Glacier mobile app that provides a map interface based on satellite images displaying all the observed glaciers in the user's proximity. Basic information is provided for each glacier, including photographs and general information on size and elevation. The app is designed to reach out to the general public to raise awareness on glacier changes and their implications in our daily lives.

Scientific cooperation and synergies between UNESCO-IHP and GEWEX could strengthen the capacity of Member States to make science-based decisions.

Drawing on more than four decades of experience, IHP fosters and consolidates cross-disciplinary networks that facilitate cooperation within research and capacity building, and development of analytical tools and data sharing, primarily across national boundaries. IHP also enhances awareness of policy-makers at the national, regional and international level on the predictions and risks related to these changes, taking into account the impact of global change, including climate change and human impact.

GEWEX is dedicated to understanding the Earth's water cycle and energy fluxes at the surface and in the atmosphere, and it coordinates science activities to facilitate research into the global water cycle and interactions between the land and the atmosphere. Collaboration between IHP and GEWEX based on scientific studies could provide adaptation recommendations to respond to local and regional needs and to meet global water challenges.

IHP and GEWEX could develop synergies and scientific cooperation in the Grand Challenge "Changes in Water Availability" led by GEWEX on:

1. Observations and Predictions of Precipitation;
2. Global Water Resource Systems;
3. Changes in Extremes and
4. Water and Energy Cycles and Processes.

IHP is already a partner with the GEWEX project INARCH,

the International Network for Alpine Research Catchment Hydrology, to better understand hydrological processes, improve their forecasts and find consistent measurement strategies in cold regions.

Strengthening the collaboration between IHP and GEWEX to further promote linkages and synergies will be an asset to improving the dissemination of research results among different regions and multiple languages. It is also expected to strengthen knowledge transfer and capacity building in developing countries through training and exchanges, building on existing IHP and GEWEX networks.

There is also an opportunity to continue driving scientific cooperation to implement the recently adopted international development agenda and Paris climate agreement, as they create new opportunities to strengthen the link between scientific knowledge and public policy to consolidate integrated water resources management in the long term.

Reference

UNESCO-IHP, 2014. IHP-VIII: Water Security Responses to Local, Regional, and Global Challenges. <http://en.unesco.org/themes/water-security/hydrology/IHP-VIII-water-security>.

**Winners of the
Early Career Researcher
Video Competition**

GEWEX and the World Climate Research Programme are pleased to announce two winners of the Early Career Researcher Video Competition for the North American Regional Hydroclimate Project: Theodore Letcher of the University at Albany and Joshua Roundy of the University of Kansas. Both submitted videos addressing the water challenges facing the Western United States and Canada. Each will receive \$500 and be invited to be a member of the Early Career Researcher Advisory Panel for the new GEWEX North American Regional Hydroclimate Project.

Congratulations to the winners. We look forward to working with them on this exciting project.

Mapping the 2015 South Carolina Flood Using SMAP and GPM Measurements

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Obtaining cloud-free images to map land-surface inundation, especially following major rain events, is a problem, as visible and infrared sensors cannot penetrate through clouds. A first analysis of flood monitoring was conducted using two new satellite systems to examine satellite-based mapping of the historic severe floods in South Carolina during 4–7 October 2015. Rainfall was derived from the Global Precipitation Measurement (GPM) Mission and soil moisture from the Soil Moisture Active and Passive (SMAP) satellite. SMAP is a microwave all-weather sensor with cloud penetration capability and despite its lower spatial resolution (about 36 km) as compared to visible and infrared sensors (about 1 km), it can be harnessed for inundation mapping. The data from GPM and SMAP missions were used to map the spatial extent of the wetness and the soil moisture drydown.

Background

The United Nations Office for Disaster Risk Reduction estimates that between 1995 and 2015 there were over one hundred major floods resulting in the loss of over 150,000 lives, affecting over 2 billion people and loss in property totaling billions of dollars (Guha-Sapir et al., 2015). Floods by far constitute the largest proportion of weather-related disasters as compared to droughts, wildfires and landslides. In the last decade, many of these floods have occurred in the developing countries of Asia and Africa (<http://www.munichre.com/en/re-insurance/business/non-life/natcatservice/significant-natural-catastrophes/index.html>), which lack flood control infrastructure critical to controlling the extent of flooding. These regions also lack the resources for an observing network that can provide the information necessary for the monitoring, prediction and relief efforts of large-scale floods. Satellite remote sensing can play an important role in these regions. Unlike in the United States where there are ample rain gauge and stream gauge networks, globally there are many areas, particularly in developing countries, where there are no rain or stream gauges.

In the first few days of October 2015 a series of atmospheric events led to record-breaking rainfall and subsequent floods in South Carolina, USA. The extreme meteorological events created a rare persistence of interaction between mid-latitude and tropical weather systems. In late September, a cold front pushed southeast into the Atlantic coastal region ahead of an amplifying upper level trough. Meanwhile, Hurricane Joaquin developed well south of Bermuda, moved west, then south-

west, then stalled over the Bahamas by 1 October. The trough over the southeastern United States cut off and tapped the tropical moisture associated with Joaquin, pulling a plume of moisture-laden air up and over the stalled front and creating a sequence of training convective systems focused on South Carolina. Thus, despite the fact that Joaquin never directly contributed rain to the southeastern states, it was an integral contributor to the extreme event. During the period of 1–4 October this configuration persisted, with the cut-off trough, stalled front, nearly-stationary Joaquin, and conveyor belt of moisture, fitting the definition of a nearly stationary atmospheric river. Subsequently, Joaquin mobilized to the northeast, impacting Bermuda, and the trough swept up the coast, taking the front out to sea and ending the deluge. Significant effects were felt all along the Atlantic Coast, with excessive rainfall and strong on-shore winds extending to the Maritime Provinces of Canada. Halverson (2015) provides an insightful analysis of this event.

In the past, flood mapping has been done by use of visible and near-infrared sensors such as the Moderate Resolution Imaging Spectroradiometer (MODIS) (Sakamoto et al., 2007; Ordoyne and Friedl, 2008; Islam et al., 2010; Oglivie et al., 2015). However, these sensors cannot penetrate cloud cover, which can persist for several days during heavy precipitation and hinder flood mapping. The following is an examination of the synergistic use of satellite-based precipitation and soil moisture observations. Both the precipitation and soil moisture sensors operate in the microwave region of the electromagnetic spectrum and can “see” through clouds in varying degrees depending upon the wavelength. However, microwave observations have a drawback with respect to spatial resolution. The spatial resolution of most microwave sensors is at least an order of magnitude poorer than visible and near infrared sensors. The spatial resolution of MODIS is on the order of 250 m and those of the microwave sensors for precipitation and soil moisture is 10–40 km. Precipitation observations along with soil moisture provide the precedent conditions necessary to forecast large-scale flooding events (Bindlish et al., 2009).

Study Area, Data and Methods

The study area is the state of South Carolina, U.S., shown in Figure 1. The box in that figure is the region that was used to average and calculate the precipitation and soil moisture, as well as determine the peak rainfall. The dot denotes the location of a stream gauge on the Black River near Kingstree, SC; the data from this gauge are used for comparisons to the satellite data in this paper. The United States Geographic Survey (USGS) prepared a report (Feaster et al., 2015) summarizing the ground observations at many stream gauges in South Carolina—stage and discharge, before and after the October flood event.

Global Precipitation Measurement (GPM) Mission

The GPM Core Observatory is a joint National Aeronautics and Space Administration (NASA)–Japan Aerospace Exploration Agency (JAXA) mission launched in February 2014



Figure 1. The box shows the region where the rainfall and soil moisture data from the satellite sensors were averaged for analysis. The black dot indicates the location of the gauge on the Black River in Kingstree, SC.

into an inclined orbit that covers the $\pm 65^\circ$ latitude band (Hou et al., 2014). The Observatory has two instruments: the Dual-frequency Precipitation Radar (DPR) built by JAXA and the GPM Microwave Imager (GMI) built by NASA. The active radar DPR delivers 3-dimensional data through the atmospheric column, providing information on particle size distributions and precipitation intensity (Hou et al., 2014). The passive conically scanning radiometer GMI (Draper et al., 2015) provides an integrated view through the precipitation column, effectively totaling up the amount of liquid precipitation and frozen precipitation within the field of view. The GPM Core Observatory serves as an anchor to unify the rain and snow estimates from a constellation of domestic and international satellites with precipitation radiometers under partnership with GPM. In 2015 there were 10 partner sensors (Huffman et al., 2015). With the calibrated precipitation estimates from this constellation of sensors, along with infrared data to fill in the few temporal gaps, the merged precipitation product developed by NASA is called the Integrated Multi-satellite Retrievals for GPM (IMERG). There are many other precipitation products available from the individual sensors of the GPM Core Observatory and constellation partners. IMERG provides precipitation estimates from $\pm 60^\circ$ latitude, every 30 minutes for a $0.1^\circ \times 0.1^\circ$ surface grid box resolution. The IMERG products are freely available with five-hour data latency to application users (e.g., for flood and landslide susceptibility mapping and cyclone location fixes and intensity). High-quality, scientific research-level IMERG products are also delivered about three months after observation with all ancillary data included in the post-analysis algorithm methodology. In this study we use the Version 3 IMERG daily-accumulated rainfall product from GPM.

Soil Moisture Active Passive (SMAP) Satellite

The NASA SMAP satellite was developed specifically to map and monitor surface soil moisture (Entekhabi et al., 2010). Like the European Space Agency's Soil Moisture Ocean Salinity (SMOS) mission, SMAP utilizes an L-band microwave radiometer to obtain brightness temperature at a nominal 36-km spatial resolution. SMAP uses a conical scanner with a fixed incidence angle (40°). The SMAP radiometer system was designed to mitigate radio frequency interference (RFI) to the degree possible, a problem that has plagued SMOS in several regions of the world. SMAP also incorporated a high resolution L-band radar that provided concurrent backscatter measurements. The major advance that SMAP had to offer was an enhanced 9-km spatial resolution product derived by combining the active and passive observations. This higher resolution product can support a wider range of applications. SMAP was launched on 31 January 2015 and began providing routine observations in late April 2015. Evaluations of the radiometer, as well as the active-passive product, indicated good performance over the core validation sites that met the mission requirement of $0.04 \text{ m}^3/\text{m}^3$ (Chan et al., 2016). However, on 7 July 2015, the radar failed and ceased providing data. The radiometer has continued to operate and expanded validation has shown it provides quality soil moisture information, including regions where SMOS cannot. Various methods of enhancing the spatial resolution of the radiometer-only product are being investigated. In this study a value-added product was used that over-samples the SMAP volumetric soil moisture data with a spatial resolution of 36 km and posts it on a 9-km grid.

Results

The rainfall estimates from IMERG at a 0.1° (approximately 10 km) spatial resolution are shown in Figure 2 on page 1. It can be seen that the accumulated rainfall as recorded by GPM is parallel to the east coast on 3 October and progressively (4, 5 and 6 October) moved into the counter-clockwise direction. The peak daily-accumulated rainfall in the center of this oval pattern ranges from 635–762 mm on 3–5 October and then the system loses organization on 6 October. On 3–5 October, the rainfall was organized in an elliptical pattern with the peak rainfall accumulation in the center ranging from 635–762 mm and decaying to around 51 mm at the edges of the ellipse.

While GPM captures the wetting, SMAP observes the dry-down. Figure 3 (next page) shows a pattern that is consistent with the precipitation described in the previous paragraph, where the volumetric soil moisture is shown for the eastern part of the U.S. that corresponds to the descending orbits (6 AM equatorial nadir crossing time) between 30 September and 24 October 2015. SMAP provides a global coverage in 2–3 days using the descending orbits only. There is no SMAP coverage on some days due to its orbit characteristics (28–29 September; 6–7 October). SMAP is a polar orbiting satellite with an exact repeat of 8 days; therefore, the SMAP swath coverage is the same every 8 days (1, 9 and 17 October have the same coverage area).

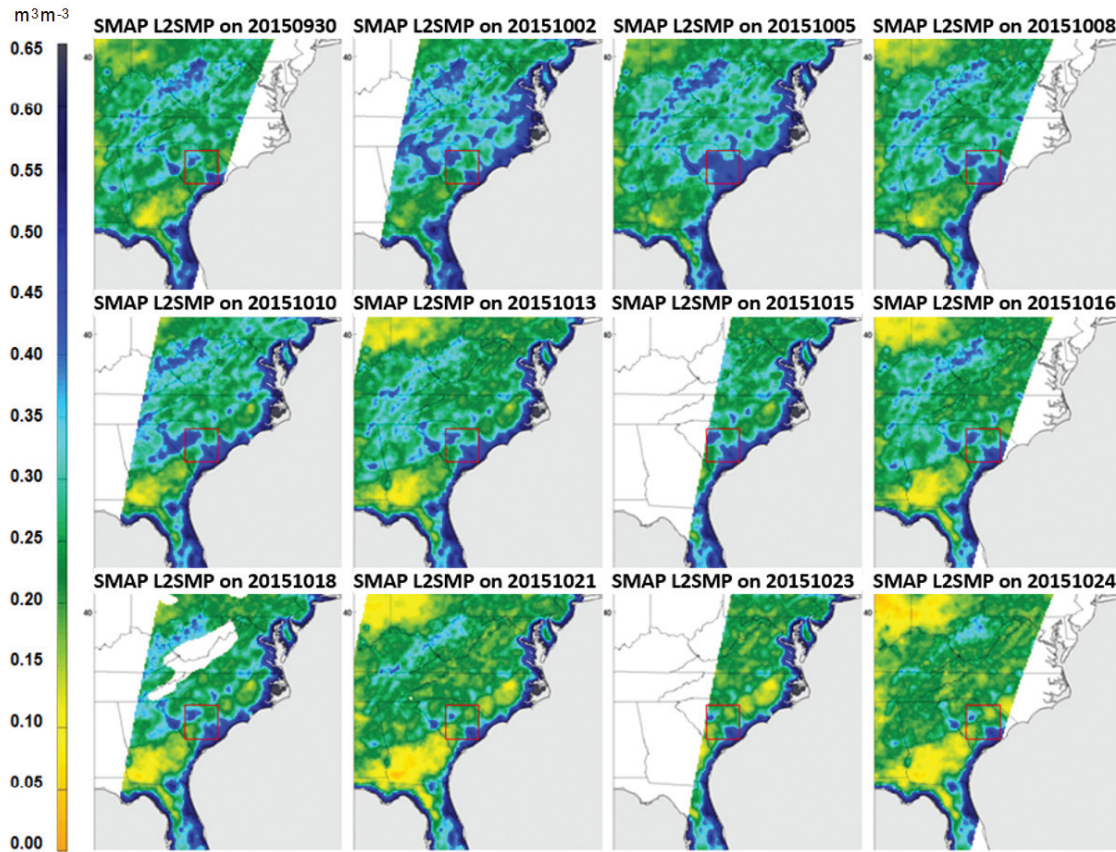


Figure 3. Soil moisture increase (prior to 5 October) and drydown observed using SMAP.

Figure 3 shows the soil moisture was relatively constant on 27–30 September. After the rainfall on 30 September–4 October (Figure 2), there is an increase in the saturated area (denoted by the bright blue color) that reaches a peak on 5 October and then begins to decay. The orientation of this wet region is along the same direction as the peak rainfall (about 30–45 degrees counter-clockwise from the vertical direction).

USGS Station 02136000 at Black River at Kingstree, SC (Feaster et al., 2015) recorded an increase in cumulative precipitation (from 1–5 October 2015) as 38.1 mm on 2 October, 127 mm on 3 October, 508 mm on 4 October and 584.2 mm on 5 October. The National Weather Service (NWS) flood stage for this location is 3.66 m above datum and a discharge of 25.48 cubic meters per second and the corresponding numbers for the moderate flood stage and major flood stage are 4.3 m and 4.9 m and 56.6 m^3s^{-1} and 113.86 m^3s^{-1} (corresponds to the moderate and major flood discharge). In this flood event the peak observed stage was 7 m and the corresponding stream discharge of around 2378.6 m^3s^{-1} (Feaster et al., 2015).

Figure 4 on page 10 shows the area-averaged GPM precipitation and the SMAP soil moisture corresponding to the box in Figure 1. GPM accumulated rainfall on 1–5 October 2015 generally over-estimated the NWS rainfall totals for the same

period by about 20% (Feaster et al., 2015). It can be observed in the figure that due to the rainfall (in increasing daily accumulation) during 1–5 October, the soil moisture as estimated by SMAP increases, as does the gauge height recorded on the Kings River at Kingstree, SC (Table 1). The average precipitation in the box was 4 mm on 1 October, 7 mm on 2 October, 38 mm on 3 October, 261 mm on 4 October and 306 mm on 5 October, followed by 29 mm on 6 October and negligible or no rain from then until 26 October. The peak-recorded rainfall in the box was 41.91mm, 74.67 mm, 138.68 mm, 421 mm, 567 mm and 188 mm for 1–6 October, respectively. The average volumetric soil moisture (m^3m^{-3}) in the box was 0.33 on 2 October and 0.42 on 5 October, followed by a gradual decrease to 0.38, 0.36, 0.34, 0.32, 0.27 and 0.25 on 7, 10, 13, 16, 21 and 24 October. The stage on the Black River at Kingstree, SC increased from 0.069 m on October 1 to 6.9 m on October 7 and decreased gradually to 2.75 m on 26 October. The discharge also shows a similar pattern (Table 1). The highest soil moisture for the study domain was observed on 5 October 2015. This was also when the peak precipitation was observed over the study area. The study domain received an additional 25 mm of precipitation on 6 October. No precipitation was recorded after 6 October. In fact the peak discharge and stage height is on 7 October, two days after the highest rainfall (peak or average of the box). This shows that there is

a two-day lag between peak rainfall and the discharge on the Black River at Kingstree, SC. The precipitation received on 4–5 October fell on saturated soil conditions resulting in high surface runoff. This runoff contributed to high streamflow conditions on 7 October. The precipitation along with the soil moisture estimates provide two of the key variables to improve estimates of flooding over this area. Figure 4 on the next page shows that the drydown in soil moisture corresponds well to the decrease in stage height at Kingstree, SC.

MODIS could not image this flooding event until after the onset of widespread major flooding due to cloud coverage. Clear-sky MODIS Aqua and Terra images for the flooded period are available only after the flooded period on 7 October 2015 and there are no subsequent cloud-free days until 14 October, when flood extent had subsided.

Implications for Future Flood Events

The use of microwave sensors provides a unique opportunity to monitor the land surface in the presence of clouds. This ability is critical for flood forecasting since rainy periods preceding the onset of large-scale flooding naturally tend to be associated with extensive cloud cover. This limits the value of visible/infrared sensors for flood forecasting and monitoring purposes. Remote visible and infrared sensors provide higher resolution imaging during cloud-free days, but it is critical to supplement these images with microwave observations on cloudy days.

Due to the difficulty of retrieving cloud-free MODIS images over areas with active flooding, microwave estimates of soil moisture and precipitation can be used to provide approximate areas of potential inundation. This is the first synergistic approach to using GPM observed rainfall and SMAP soil moisture as an alternative to visible-near infrared sensors. SMAP data have a large swath of 1000 km and can provide a temporal revisit on the average of every 2–3 days. This has the potential to greatly influence the performance of the GPM precipitation retrievals through providing soil moisture estimates that can be incorporated into land surface emissivity models and estimates. For the passive sensors of GMI and the GPM constellation partners, surface brightness temperature contributions can sometimes overwhelm or confuse the brightness temperature contributions from the precipitation in the atmospheric column. Together, SMAP and GPM can provide information on the surface water fluxes—an important quantity for assessing and monitoring the Earth’s fresh water resources. Therefore, integrated SMAP plus GPM data have the potential to provide a greater understanding of our complex Earth system. The soil wetting (via precipitation) and the soil drydown processes and statistics for various surface and soil types is an important element for improving land surface models and eventually weather forecasting and global climate models. Integrated GPM and SMAP data can serve as key tools for application users and emergency management to assess the extent and potential impact of flooding events among other hydrometeorological phenomena.

Table 1. GPM precipitation (mm), SMAP soil moisture (volumetric) averaged over the box centered in South Carolina and the stage and discharge for the Black River at Kingstree, SC between 1 and 23 October 2015.

Month/Day/Year	GPM Precipitation (Mean-mm)	SMAP L2SMP-D (Volumetric)	Kingstree Gauge Height (m)	Discharge m ³ /sec
10/1/2015	4	***	0.7	1.50
10/2/2015	7	0.33	.8	168.90
10/3/2015	38	***	1.3	280.68
10/4/2015	261	***	2.3	1157.76
10/5/2015	306	0.42	4.7	18970.53
10/6/2015	29	***	6.5	110789.48
10/7/2015	0	0.38	6.9	214723.46
10/8/2015	0	0.36	6.5	207032.62
10/9/2015	0	***	5.7	137395.95
10/10/2015	0	0.36	4.9	74144.71
10/11/2015	51	***	4.3	39901.20
10/12/2015	2	***	4.0	25786.70
10/13/2015	0	0.34	4.1	21963.08
10/14/2015	0	***	4.1	24972.59
10/15/2015	0	0.34	3.9	21959.11
10/16/2015	0	0.32	3.7	17412.28
10/17/2015	0	***	3.6	14175.67
10/18/2015	0	0.32	3.5	11915.14
10/19/2015	0	***	3.4	10278.43
10/20/2015	0	***	3.3	8914.13
10/21/2015	0	0.27	3.2	7733.88
10/22/2015	0	***	3.1	6709.95
10/23/2015	0	0.27	3.0	5838.08
10/24/2015	0	0.25	2.9	5163.85
10/25/2015	0	***	2.8	4605.44
10/26/2015	0	0.25	2.8	4156.91

*** No coverage available for these dates

Acknowledgements

The authors thank the NASA Earth Sciences Program and Jared Entin, the Terrestrial Hydrology Program Manager, for providing funding to enable this research.

The SMAP soil moisture data are available via the National Snow and Ice Data Center at: <https://nsidc.org/data/smap/smap-data.html>

The GPM data are available at: <ftp://jsimpson.pps.eosdis.nasa.gov/NRTPUB/imerg/gis/2015/10/> with names of the form:

3B-HHR-LMS.MRG.3IMERG.201510xx-S000000-E002959.0000.V03E.1day.tif

where “xx” is the two-digit day of October under analysis. The coordinates of the bounding box used in the study in (latitude/longitude) are: Upper Right (34.8,-81.74), Lower Left (33.14,-79.68). The first time a user accesses the site a free, automatic registration is required.

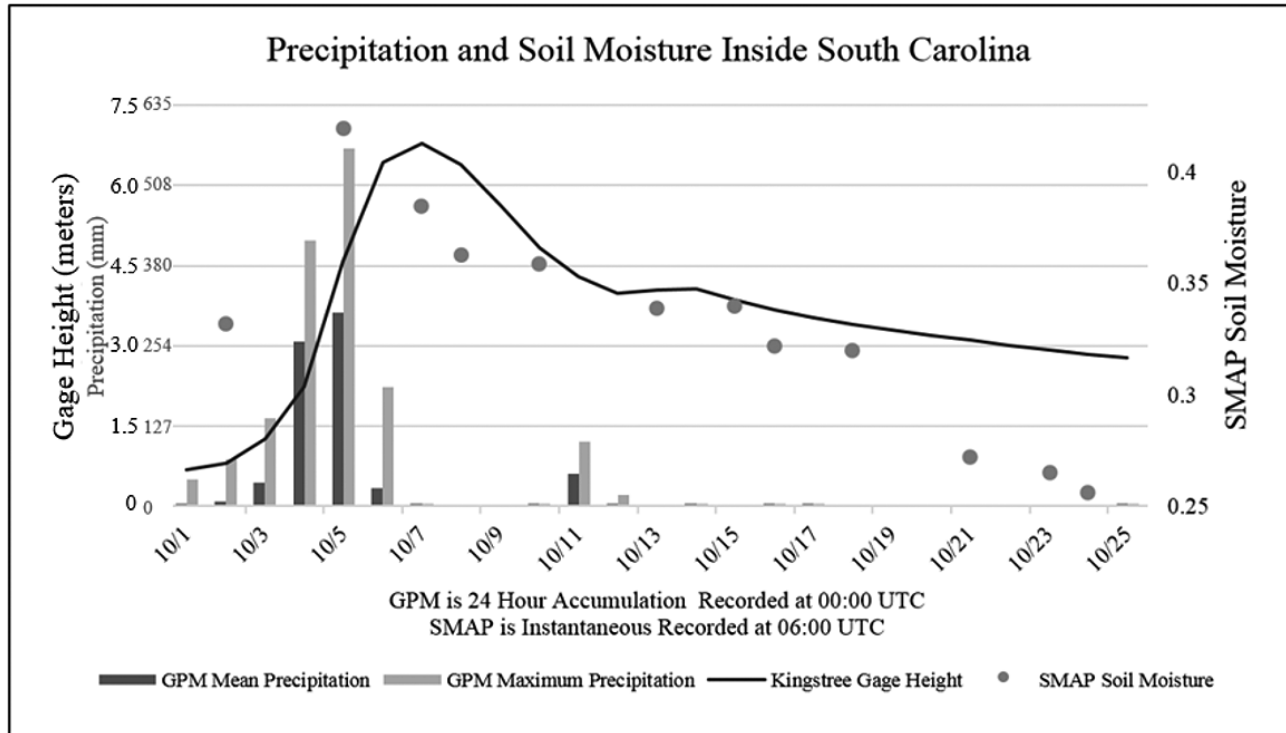


Figure 4. Co-variability of GPM daily-accumulated precipitation (mm) along with SMAP volumetric soil moisture and gauge height of the Black River in Kingstree, SC between 1 and 25 October 2015.

Acknowledgements (Continued)

The Kingstree, SC gauge height and discharge information is at: http://waterdata.usgs.gov/sc/nwis/uw?site_no=02136000

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Meeting/Workshop Reports

Annual Meeting of the GEWEX Data and Assessments Panel (GDAP)

29 September–2 October 2015
Xiamen, China

Jörg Schulz

European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), Darmstadt, Germany

The GDAP meeting was generously sponsored by the China Association for Science and Technology, the Chinese Academy of Sciences (CAS), the Chinese National Committee for Future Earth, the State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics and the CAS Institute of Atmospheric Physics. The Chinese Meteorological Administration gave a presentation on the Chinese Meteorological Satellite program, which provides long-term operational measurements with a high potential to support GEWEX science.

GDAP activities are currently divided into two major areas: Data Products and Product Quality Assessments. The individual and integrated GEWEX data products enable research related to the WCRP Grand Challenges on changes in water availability, clouds, climate sensitivity, and potentially for climate extremes. Major objectives of the product quality assessments are to provide independent and transparent quality assurance for existing data records, to identify key limitations in data records to stimulate improvements, and to allow objective selections of appropriate data records. In addition, GDAP shares responsibility with the Global Climate Observing System (GCOS) for the Baseline Surface Radiation Network (BSRN), which is essential to setting standards and providing high quality radiation measurements for the evaluation of satellite data sets and climate models.

New directions discussed at the meeting included how GDAP can contribute to the GEWEX Upper Tropospheric Clouds and Convection Process Evaluation Study (UTTCC PROES), reprocessing ground-based precipitation radar data in support of several WCRP Grand Challenges, and developing a methodology for uncertainty characterization for satellite-derived data sets.

GDAP Data Sets

The full reprocessing to generate the **International Satellite Cloud Climatology Project** Version 2 (ISCCP V2) data set will begin in 2016. A “final” version of the ISCCP cloud products from 1983 to the present will be available soon.

Version 2.3 of the **Global Precipitation Climatology Project** (GPCP) data is in final testing. This version fixes problems

with cross-calibrations among satellites that produced artificial shifts in the data and uses the new Global Precipitation Climatology Centre (GPCC) full analysis.

The **Surface Radiation Budget Project** (SRB) continues to assess new neural network High Resolution Infrared Radiation Sounder (nnHIRS) and ISCCP HX data sets, make algorithm improvements and analyze test cases. SRB is testing the use of the land surface temperature product from LandFlux and the diurnal ocean surface skin temperature from the SeaFlux Project. SRB derives a 3-hourly blended global surface skin temperature input using these and the ISCCP HX skin temperature retrievals. This represents the next stage in energy flux integration.

The **SeaFlux Project** produced a climate data record with extensions towards real time from Special Sensor Microwave Imager/Sounder (SSMIS) instrument data for the period of 1988–2007. Neural network derived winds were used instead of the cross-calibrated multi-platform wind product, which reduced the trend in global wind speed. Comparison activities have shown that both latent heat and sensible heat fluxes show inter-product differences of 5–10 Wm^{-2} globally and 10–20 Wm^{-2} over the Southern Ocean. Several of the products show a moderate trend from the early 1990s, which is in contrast to the Woods Hole Oceanographic Institute’s Objectively Analyzed Air-sea Fluxes (OAFflux) data and some reanalysis products. At the global scale, temperature, humidity and wind speed differences appear to be important, and offsetting in some cases. Wind speed is in better overall agreement than humidity and temperature differences.

The **LandFlux Project** has made good progress towards completion of the Version 1 global land surface heat fluxes. Simulations covering the period 1984–2007 have been completed using four different methodologies with 1-degree 3-hourly latent heat fluxes. Work is continuing on the development of a global sensible heat flux product to be completed in 2016.

A validation study of the LandFlux product against 45 globally distributed flux towers was recently undertaken (McCabe et al., 2015), providing a first comprehensive evaluation of LandFlux data sets. In a parallel effort, findings from the European Space Agency (ESA) funded Water Cycle Observation Multi-mission Strategy-EvapoTranspiration (WACMOS-ET) Project have also been published, supporting the research being undertaken by investigators within LandFlux (Michel et al., 2015 and Miralles et al., 2015).

SRB used HIRS products together with SeaFlux and LandFlux surface values, along with the latest ISCCP and the Max-Planck-Institute Aerosol Climatology Version 1 (MAC-V1) aerosols to compute fluxes. The shortwave (SW) fluxes look quite good and are ready for distribution, but the longwave (LW) fluxes are biased positive (downwelling is too large) 7 W/m^2 over oceans for a net 5 W/m^2 bias globally. The HIRS humidity profiles have limitations in the lower atmosphere and close to the surface because there is no HIRS channel that has high sensitivity to water vapor and the lower part of the



Participants at the Annual GDAP Meeting in Xiamen, China.

profile is estimated basically from the differential absorption in window channel differences. Discussion is ongoing regarding using reanalysis instead. However, the National Aeronautics and Space Administration’s Modern-Era Retrospective Analysis for Research and Applications (MERRA) ended in December 2015 and some biases found in MERRA-2 data in comparison to BSRN station data have increased and need to be understood. The use of European Centre for Medium-Range Weather Forecasting (ECMWF) reanalysis data presents an alternative, but interfacing it with SRB and analyzing the results would be a major undertaking.

Completion of an **integrated product** that uses common assumptions across the suite of GDAP products is expected in 2016. It is designed to ensure that geophysical signals and their covariance are tied to the data and products themselves rather than inconsistencies in their assumptions. The nnHIRS product, a retrieval of temperature and humidity profiles, is essential to providing temperature and humidity profiles, as well as several surface parameters for the integrated product. Due to issues detected when using earlier versions of the nnHIRS product to compute LW radiative fluxes, the latest version was adjusted to improve agreement with surface station temperatures and humidity. All other ancillary products needed for the integrated product have been completed for the entire time period (currently 1980–2014) and are online. Nearly all products for the integrated product are ready to produce data from 1998 onwards, with only the finalization of ISCCP products for SRB and the decision on the use of temperature and humidity profiles for the LW fluxes outstanding.

GEWEX Data Quality Assessments

The Fifth GEWEX **Water Vapor Assessment** (G-VAP) Meeting was held at the University of Wisconsin in November 2015 (see report in the February 2016 issue of *GEWEX News*). The water vapor assessment is expected to be finalized by the time of the next GDAP meeting in 2016, when the G-VAP

proposal for the biennial reporting of water vapor scientific findings relevant to GEWEX will be discussed.

The final report of the **aerosol assessment**, “A Critical Review of the Efficacy of Commonly Used Aerosol Optical Thickness Retrievals: Literature Assessment,” was presented at the GDAP meeting. Publication will follow in 2016.

For the new **precipitation assessment**, key questions for the different phases of the project were identified and high priority was given to evaluating the GPCP climatology. Participating data sets, including reanalysis results, will be identified in 2016. The Global Precipitation Mission radar, ground radar networks and gauge analyses may be helpful for assessing uncertainties from multiple angles if carefully analyzed, keeping individual strengths and weaknesses in mind. Meanwhile, the precipitation assessment team continues to identify key problems for subsequent assessment cycles. Extreme precipitation is among the top priorities after the climatology. Understanding and quantifying the potential uncertainties in the GPCP climatology is of urgent importance to address the budget closure issues of the integrated products.

A white paper on the identification of the evaluation metrics and approaches needed to verify whether products comply with the standards will serve as a baseline for the **soil moisture assessment**. While the interest and need for an assessment of the various products from satellite, reanalysis and models exists, progress has been hampered by how long it has taken to come to an agreement on how to conduct the evaluation.

The GDAP paper on “**Data Set Quality Assessments: Needs, Benefits, Best Practices and Governance**” has been published by the WCRP Data Advisory Council (WDAC). The paper, which has been reviewed across the WCRP programs, provides guidance towards a more homogeneous approach to assessments of data set quality and is expected to be endorsed at the next WDAC meeting in April 2016.

Ground Based Networks and Radar Data Records

The **Baseline Surface Radiation Network** (BSRN) has a new project leader, Charles Long of the National Oceanic and Atmospheric Administration (NOAA). The Alfred Wegener Institute (AWI) hosts the World Radiation Monitoring Center (WRMC, <http://bsrn.awi.de/>), the central archive of BSRN data, which contains over 700 years of BSRN station data that are heavily used and have been cited in over 1200 peer-reviewed articles. Fifty-nine stations provided data to the BSRN archive in 2015. BSRN is directly participating in the World Weather Research Programme Polar Prediction Project and several stations are a part of the International Arctic Systems for Observing the Atmosphere (IASOA) Radiation Working Group.

The **International Soil Moisture Network** (ISMN) serves a large international scientific community through improvement of weather and climate models and remote sensing products, and provides support to agriculture applications. ISMN is coordinated by GEWEX/GDAP in cooperation with the Group on Earth Observations (GEO) and the Committee on Earth Observation Satellites (CEOS). The ISMN database is hosted by the Department of Geodesy and Geoinformation at the Vienna University of Technology (TU Wien). ISMN integrates 49 networks containing almost 2050 stations (1600 last year) that have added over 8000 soil moisture data sets (6500 last year) into the archive. It also contains historical soil moisture data sets dating back to 1952. Operational data sets are updated in near-real time. ISMN is rapidly growing and several new networks and data sets will be integrated in the near future, including China (Wuhan University), Korea, and Romania. Further growth potential, such as adding the hundreds of soil moisture stations operated by the Chinese meteorological service, was discussed at the GDAP meeting with Chinese representatives giving positive signals on a potential integration.

Activities related to radar data reprocessing are far less mature than for satellite data. Thirty years ago, we were in a similar state with regard to satellite data, when it was understood that satellite data could be used for more than weather forecasting or other real-time applications. GDAP plans to work towards a similar extension of the usage of radar data by coordinating and synthesizing activities. Even if the problem of global radar data exchange cannot be solved, a first step by GDAP would be to approach all radar data operators to request that they store their radar data in a format that could be utilized by scientists decades later. As this is a cost-intensive process, it is necessary to demonstrate that there is a much bigger spectrum of potential uses for radar data beyond weather. For instance, documenting changes in climate extremes requires high temporal resolution data sets. The collection of GEWEX data sets could be analyzed in that respect, but surface radar data could be a new source for analyzing precipitation extremes.

NOAA has completed reprocessing of Next Generation Radar (NEXRAD) data for the period covering 2001–2012. The re-analyzed data are available at 1-km and 5-minute resolution.

An important step in the process of generating the best possible precipitation estimates is to assess the bias in the radar-only product and to implement techniques for merging in situ data and providing the best bias-adjusted estimates. The Deutscher Wetterdienst (DWD) has completed reprocessing of DWD radar data since 2001 (for Germany), including statistical evaluation with a focus on extreme precipitation and the development of user-specific products for applications (e.g., hydrology, civil protection and agriculture).

Although this was attempted years ago without success, GDAP will again try to assess the value of a new project that brings together scientists working on radar reprocessing, considering aspects of archiving, reprocessing, and exchanging radar data and the development of consistent radar precipitation databases for use in hydroclimatological studies. A workshop on this is planned for 2017.

GEWEX UTCC PROES

The goal of the activities of the GEWEX Upper Tropospheric Clouds and Convection Process Evaluation Study (UTTC PROES) is to provide observational-based metrics for a better understanding of climate related physical processes. One of the WCRP Grand Challenges is to determine the role of convection on cloud feedbacks. The objective of the GEWEX UTCC PROES Working Group is to better understand the interconnection between convection and the heating induced by the outflowing anvils. Widening the focus to the role of all cirrus clouds leads to another key question: how large are the relative cirrus contributions, in occurrence and in radiative heating, originating from convection and from in situ freezing driven by large-scale forcing?

At present the Working Group includes about 30 scientists. The first workshop was held on 16 November 2015 in Paris, France, where feedback hypotheses were presented and discussed, and resources identified to tackle the following scientific topics: (1) cloud systems and atmospheric environment from observations; (2) Lagrangian transport to determine cirrus origin and life cycle; (3) process modeling and large-scale parameterizations; and (4) radiative transfer. The analysis of large-scale convective cloud systems shows that the size of these systems is strongly linked to their convective strength.

UTTC PROES will build a synergetic database of high-altitude cloud systems to be used by the participants. In addition, a simulator of high-altitude cloud systems is being built for the evaluation of different formation schemes in climate models. Informal meetings will be held whenever the coordinators have the occasion (during conferences or visits); and a second workshop is planned for autumn 2016 in New York.

Uncertainty Analysis

Uncertainty analysis is important in making GEWEX related products useful for answering the GEWEX Science Questions. Within Europe, two projects have begun that address the uncertainty characterization of satellite data records. One is Fidelity and Uncertainty in Climate Data Records from Earth Obser-

vations (FIDUCEO); the other is the Gap Analysis for Integrated Atmospheric ECV Climate Monitoring (GAIA-CLIM), which addresses the uncertainty of surface-based reference observations and their use to characterize satellite measurements. In addition, GEWEX data set producers and assessments have further addressed how uncertainty might be quantified in products and through comparisons with other data.

GDAP supported a recent workshop on uncertainties in water vapor measurements at 183 GHz (see report in November 2015 issue of *GEWEX News*), where biases observed between measurements at 183 GHz and calculations using different radiative transfer models were discussed, including using either radiosondes (RAOBS) or short-range forecasts from Numerical Weather Prediction (NWP) systems. The primary objectives of the workshop were: (1) describe the biases, trying to separate the biases that were common to all approaches from those which may have been a result of a particular methodology; (2) identify and, where possible, quantify uncertainty in every component of the comparison; and (3) begin the process of bias attribution where possible, which could in due course lead to bias elimination. In order to address these ambitious goals, experts in many different aspects were assembled. This included specialists in RAOBS calibration, NWP models and data assimilation, instrument biases and radiative transfer models, both the models themselves and the underlying spectroscopy. Comparisons were also undertaken with other techniques for sensing humidity information such as Global Navigation Satellite Systems (GNSS), Differential Absorption Lidar (DIAL), Raman Lidar and infrared radiances.

GDAP will continue to support such activities to achieve better overall uncertainty characterization of satellite-derived data sets. ESA and EUMETSAT are planning a workshop on uncertainty characterization for satellite data sets in 2017.

Next Meeting

The next annual meeting of GDAP and the kickoff workshop for the precipitation assessment is tentatively scheduled for fall 2016 in Washington, DC.

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Annual Meeting of the GEWEX Hydroclimatology Panel

Entebbe, Uganda
17–19 November 2015

Jason Evans¹ and Jan Polcher²

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The GEWEX Hydroclimatology Panel (GHP) meeting was held to evaluate the ongoing and planned activities of the Panel to ensure that they are effectively contributing to the leading role that GEWEX plays in hydrological sciences and related modeling activities. Updates were provided for each element of the two main components of GHP—the Regional Hydroclimate Projects (RHPs) and the research topic-based Crosscutting Projects. The meeting was hosted by the Uganda National Meteorological Authority on the shores of Lake Victoria.

Regional Hydroclimate Projects

The RHP project managers provided updates on recent accomplishments and future plans of the RHPs and highlighted the contributions that each one is making to address the GEWEX Science Questions. Two RHPs have successfully concluded—the Northern Eurasia Earth Science Partnership Initiative (NEESPI) and the Monsoon Asian Hydro-Atmosphere Scientific Research and Prediction Initiative (MAHASRI). NEESPI held a well-attended closing workshop in Prague in April 2015. The RHP was a great success in many respects, particularly in terms of engaging with scientists in the northern Eurasia region. MAHASRI held an international conference in March 2016 that served as its final meeting. Broad discussion of the many achievements of MAHASRI research, along with impacts that it has had on the Southeast Asia region, were reported on at the conference. We thank the long serving project leaders of these RHPs—Pasha Groisman (NEESPI) and Jun Matsumoto (MAHASRI)—for their dedicated leadership and encourage them to continue to be involved in existing projects or initiate new GEWEX activities.

The Hydrological Cycle in the Mediterranean Experiment (HyMeX) held a significant workshop in September 2015 that served as a five-year review and involved planning for the next five years. HyMeX has achieved much in its first five years, and now that the community is firmly established, it will be exciting to see how its research evolves going forward. The Changing Cold Regions Network (CCRN) RHP has been progressing well with its extension into the Mackenzie River Basin in Canada, which provides a significant increase in the cold regions research being undertaken. CCRN is connecting with research communities outside traditional GEWEX disciplines, such the ecological community, which is a very positive aspect for the RHP.

The Hydroclimate Project for Lake Victoria (HyVic) and the Australian Energy and Water Exchanges (OzEWEX) are “initiating” RHPs. While successfully building communication and sparking collaborative activities across parts of the OzEWEX community, the RHP is establishing recognition amongst the scientific community and potential funders. OzEWEX has held two annual workshops that have received strong attendance and participation. HyVic activities were highlighted, given the location and the hosts of the meeting. Significant funding has been granted to HyVic by UK agencies and this will allow many of the planned HyVic activities to begin. Further coordination and initiation work continues but progress is expected to accelerate in the coming year.

While a number of potential new RHPs were discussed, including Baltic Earth, it was the Pannonian Basin Experiment (PannEx) that has made the most recent progress. A workshop was held in Osijek, Croatia and an International Planning Committee (IPC) was established to draft a white paper defining the scientific objectives for the RHP. The IPC will form the basis for discussions at the follow-up workshop to be held in June in Budapest.

Crosscutting Projects

Two crosscutting activities—the project focused on sub-daily precipitation (INTENSE) and the International Network for Alpine Research Catchment Hydrology (INARCH) Project—reported on their activities during the past year, including holding workshops, collecting data and initiating new research

activities. A number of potential crosscutting activities have made progress towards reaching GHP project status, including the Alpine precipitation (MOUNTerrain) Project, which held a special session at the annual meeting of the American Geophysical Union in December 2016. A formal proposal to GHP to be approved as a Crosscutting Project is expected in the coming months. A new crosscut that is focused on human intervention in the water cycle is also moving forward with a workshop planned for late September 2016 outside Paris.

The Global Data Centers, including the Global Runoff Data Center (GRDC), the Global Precipitation Climatology Center (GPCC) and the International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE), presented their activities over the last year, reporting encouraging connections with some GEWEX projects, as well as potential further connections that were identified during the meeting.

Wrap Up

Overall the progress of established RHPs and the Crosscutting Projects was very good and is an indication of a productive year ahead for GHP-related science. The continued development of initiating RHPs and other potential new projects is also encouraging for the future vitality of GHP. As always, suggestions for new initiatives are welcome. The next GHP meeting is planned for October 2016 outside Paris and will include a joint session with the Global Land/Atmosphere System Study (GLASS) Panel to form stronger collaboration between the Panels.



Participants at the GEWEX Hydroclimatology Meeting in Uganda.

GEWEX/WCRP Calendar

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

3–5 May 2016—Workshop on Water Availability Grand Challenge for North America—Columbia, Maryland, USA

9–13 May 2016—ESA Living Planet Symposium—Prague, Czech Republic

10–13 May 2016—Conference on Earth Observation and Cryosphere Science—Frascati, Italy

16–18 May 2016—6th Third Pole Environment Meeting—Columbus, Ohio, USA

17–20 May 2016—CORDEX 2016: International Conference on Regional Climate Change—Stockholm, Sweden

18–20 May 2016—2nd Pan-Eurasian Experiment (PEER) Science Conference—Beijing, China

1–3 June 2016—2nd PannEx Workshop on the Climate System of the Pannonian Basin—Budapest, Hungary

2–3 June 2016—Eric Wood Symposium—Princeton, New Jersey, USA

6–10 June 2016—13th International Meeting on Statistical Climatology—Canmore, AB, Canadian

13–17 June 2016—1st Baltic Earth Conference—Nida Curonian Spit, Lithuania

20–22 June 2016—Earth's Hydrological Sensitivity to Climate Change Workshop—Exeter, UK

28–30 June 2016—GEWEX SoilWat Initiative: First Planning Workshop—Leipzig, Germany

12–21 July 2016—Summer School Alpbach 2016: Satellite Observations of the Global Water Cycle—Alpbach, Australia

18–22 July 2016—9th International Cloud Modeling Workshop—Exeter, UK

31 July–5 August 2016—Asia Oceania Geosciences Society 13th Annual Meeting—Beijing, China

15–19 August 2016—Joint 21st AMS Satellite Meteorology, Oceanography and Climatology Conference and 20th Conference on Air-Sea Interaction—Madison, Wisconsin

6–8 September 2016—GEWEX Convection-Permitting Climate Modeling Conference—Boulder, Colorado, USA

12–16 September 2016—WGNE/SPARC Workshop on Drag Processes and Links to Large Scale Circulation—Reading, UK

16–25 September 2016—CLIVAR OSC—Qingdao, China

21–22 September 2016—3rd Satellite Soil Moisture Validation and Application Workshop—New York, NY, USA

28–30 September 2016—The Anthropogenic Influences on the Global Water Cycle: From Observations to Models—Gif-sur-Yvette, France

3–5 October 2016—Annual Meeting of the GEWEX Hydroclimatology Panel—Gif-sur-Yvette, France

3–5 October 2016—Global Land/Atmosphere Study (GLASS) Meeting—Gif-sur-Yvette, France

9 October 2016—World Water Congress and Exhibition—Brisbane Australia

24–27 October 2016—3rd Open Science Meeting of the Global Land Project—Beijing, China

25–27 October 2016—8th EGU Leonardo Conference on “From evaporation to precipitation: The atmospheric moisture transport”—Ourense, Spain

31 October – 4 November 2016—24th SPARC Scientific Steering Group Meeting—Berlin, Germany

GEWEX
**Convection-Permitting
 Climate Modeling Conference**
 September 6-8, 2016
 Boulder, CO, USA

The poster features a landscape background with mountains and a sky with clouds. In the upper right, there are four globes showing different climate models or data sets. Below the globes are the GEWEX and NCAR logos.

Charting the course for climate & ocean research
CLIVAR
 Open Science Conference
 Qingdao, 2016

18-25 SEPTEMBER 2016 QINGDAO, CHINA

18, 24-25 September: Early Career Scientists Symposium
19-23 September: Open Science Conference

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