GEWEX NEWS

GEWEX is a Core Project of WCRP on Global Energy and Water Exchanges

WCRP World Climate Research Programme | WMO | UNESCO | IOC | ICSU International Council for Science

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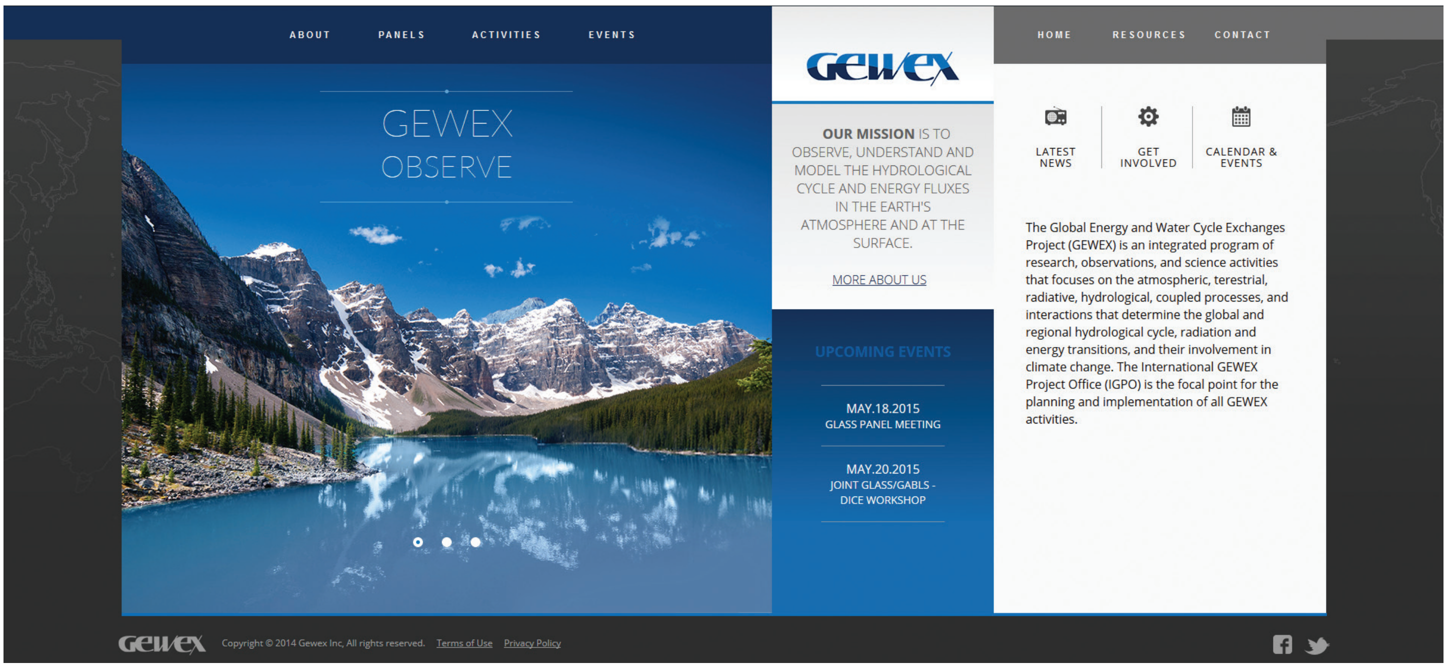

New GEWEX Website Launched!

We are excited to announce the release of the newly designed GEWEX website at *www.gewex.org*. You will notice a fresh new look with streamlined menus, simple navigation and updates with the latest information about the GEWEX Project.

New Features:

- **User-Friendly** – content is well organized so you can easily find the information you need a lot faster
- **Easy Navigation** – pages have been optimized to include easy-to-understand title headings
- **Social Media Integration** – easy access to our social media platforms
- **Mobile Ready Version** – responsive design provides optimum viewing on any mobile device
- **New Events Calendar** – easy to read dates and details; monthly, weekly and list view options
- **New Search Engine** – find pages and resources quickly

More features will be added in the next few months.

Commentary

GEWEX Activities are Well Aligned with WCRP Plans Presented at the JSC Meeting

Sonia I. Seneviratne
Co-Chair, GEWEX Scientific Steering Group

The 36th Session of the Joint Scientific Committee (JSC) of the World Climate Research Programme (WCRP) took place in Geneva, Switzerland on April 8–10. I attended the meeting with Peter van Oevelen, the Director of the International GEWEX Project Office. The emphasis of the meeting was on future directions for WCRP research, including consolidation of research in data set collection and climate change projections, and the development of new initiatives in climate and information services. The GEWEX community is very active in these areas and is a vital player in these new key developments.

Important discussions of relevance to GEWEX at the JSC meeting included the proposal of evapotranspiration as a possible new essential climate variable of the Global Climate Observing System. The importance of GEWEX data sets in climate model validation was emphasized, along with the need for improved documentation of such products for their broader use in the community (e.g., through new data set journals, which provide easy referencing with digital object identifiers). The GEWEX proposal of a new WCRP data prize, which would parallel the now established WCRP modeling prize, was well received and will be studied in the coming months.

The main GEWEX activities of the past year presented at the JSC meeting are summarized below.

Progress within GEWEX:

- Organization of the 7th International Scientific Conference on the Global Water and Energy Cycle and the Pan-GEWEX and joint Pan-GEWEX/Pan-CLIVAR meetings in The Hague, The Netherlands in July 2014
- Advances in the WCRP Grand Challenges on extremes (see *GEWEX News,* February 2015, pgs 5–7) and water availability
- Proposal of activities for the 6th Phase of the Coupled Modeling Intercomparison Project (CMIP-6, see *GEWEX News,* November 2014, pgs 6–10)
  - The Land Surface, Snow, and Soil Moisture Model Intercomparison Project (LS3MIP); the Land Use Model Intercomparison Project (LUMIP); and the High-Resolution Model Intercomparison Project (HighResMIP)
  - Two European Horizon 2020 proposals, the Coordinated Research in Earth Systems and Climate: Experiments, Knowledge, Dissemination and Outreach (CRESCENDO) and the Process-based Climate Simulation: Advances in High-resolution Modeling and European Climate Risk Assessment (PRIMAVERA), will directly or partly contribute to the model intercomparison projects.

Recent Notable GEWEX Developments and Activities:

- Substantial advances in the following new Regional Hydroclimate Projects within the GEWEX Hydroclimatology Panel (GHP): (i) Hydrology of Lake Victoria Basin (HyVic); (ii) Cold Climate Research Network (CCRN); and (iii) a planned undertaking for the US Rockies. The Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations (RELAMPAGO) in South America and PannEx in the Pannonia Basin have observational and modeling elements, and are poised to contribute to GHP goals.
- New precipitation and soil moisture assessments initiated by the GEWEX Data and Assessment Panel (GDAP)
- Initiation of the Diurnal Cycle Coupling Experiment (DICE) by the GEWEX Global Atmospheric System Studies (GASS) and Global Land/Atmosphere System Study (GLASS) Panels
- Launch of the GEWEX Soils/Water (SoilWat) Project and the GEWEX-Process Evaluation Study (PROES)
- Participation of GEWEX in the WCRP and Intergovernmental Panel on Climate Change (IPCC) Post-Fifth Assessment Report Workshop
- Coordination of the Joint Global Drought Information System (GDIS) and GHP Meeting in Pasadena, California in December 2014 (see *GEWEX News*, February 2015, pgs 10–12)

Finally, on a personal note, I would like to emphasize the importance of the proposal by Anny Cazenave, member of the JSC, to initiate the Observational Intercomparison Projects (ObsIP) or Climate Data Intercomparison Projects to formally intercompare existing observational products for climate applications. It is anticipated that these initiatives could be as significant as the well-established Modeling Intercomparison Projects (MIPS). Given the longstanding activities of GEWEX in this area, particularly within GDAP, this is a field in which our community could lead some major advances in the coming years.

Contents

Recent News of Interest

GEWEX Thanks Sam Benedict For Over 20 Years of Dedicated Support

Sam Benedict, who has a long and rich history with GEWEX, has stepped down from his position as Senior Scientific Officer. In 1990 he joined the World Meteorological Organization (WMO) in Geneva as a Senior Scientific Officer of the Joint Planning Staff and was assigned as the full-time liaison to GEWEX. More than 10 years later he retired from WMO and returned to the US, where he continued to be involved in GEWEX hydroclimate and regional projects, first as International Coordinator for the Coordinated Enhanced Observing Period (CEOP) and later as Senior Scientific Officer through 2014. We at the International GEWEX Project Office are grateful for Sam's dedicated and outstanding support throughout the years. We wish him the best in his future endeavors.

IN MEMORIAM – Eugene M. Rasmusson

Eugene M. Rasmusson passed away on 22 March 2015. Gene retired as Chief of the Diagnostics Branch of the National Oceanic and Atmospheric Administration's Climate Analysis Center in 1986 to become a research scientist at the University of Maryland, where he was later named an emeritus research scientist. His work contributed to understanding climate variability and establishing the basis for practical predictions of El Niño. His research on the water cycle was at the intersection between hydrological and atmospheric sciences, decades before it became a core approach for the GEWEX community. Gene was among a small group that promoted the first GEWEX Continental Scale Experiment (GCIP) where he contributed not only his scientific knowledge, but also his vision to strengthen the links between research and operations.

He served as president of the American Meteorological Society in 1998, and received many awards, fellowships and lectureships in recognition of his professional and scientific contributions, capped in 1999 by election to the National Academy of Engineering. Among the many recognitions he received, two stand out: the first was the prestigious Jule G. Charney Award in 1989 "for major contributions to climate diagnostics, especially of the relationship of the Southern Oscillation to climate anomalies." The second came in 1997, when he was named the Robert E. Horton Lecturer in Hydrology, with a keynote presentation on "North American Hydrology: The Evolution of an Interdisciplinary Perspective."

GASS-YOTC Model Evaluation Papers to be Published

The GEWEX Global Atmospheric System Studies (GASS) Panel has four papers on the GASS-Year of Tropical Convection (YOTC) vertical structure and physical processes of the Madden-Julian Oscillation (MJO) model evaluation project accepted for publication in the *Journal of Geophysical Research-Atmospheres*. The goal of the project was to evaluate the vertical structures of diabatic heating, moistening and momentum associated with the MJO in global circulation models and then link biases in model representations of those diabatic processes (and other physical processes) to errors in those models' simulations of the MJO. For more about the project, see: *https://yotc.ucar.edu/mjo/vertical-structure-and-diabatic-processes-mjo.*

Accepted versions of the papers are available at the following links:

Jiang et al. (2015) on analysis of the 20-year climate simulations: *https://www.dropbox.com/s/8gktyebezfgp2ui/gass-yotc-mjotf_20year_climate_final.pdf?dl=0*)

Xavier et al. (2015) on analysis of the 2-day hindcasts: *https://www.dropbox.com/s/xfu0zqyj75owi09/gass-yotc-mjotf_2day_hindcast_final.pdf?dl=0*)

Klingaman et al. (2015a) on analysis of the 20-day hindcasts: *https://www.dropbox.com/s/y9kkxuy4xyy5w8h/gass-yotc-mjotf_20day_hindcast_final.pdf?dl=0*

Klingaman et al. (2015b) on cross-experiment analysis of the nine GCMs that submitted data to all three experiments: *https://www.dropbox.com/s/w51g81t03ayxq3a/gass-yotc-mjotf_synthesis_final.pdf?dl=0*

Data Sets

All model-output data collected in this project is freely available from *https://earthsystemcog.org/projects/gass-yotc-mip/.*

Many prognostic fields are available globally; tendencies of T, q, u and v from individual parameterizations are available from 50°S–50°N. Full vertical profiles of all fields are available every 6 hours (for the 20-year climate simulations), every 3 hours (for the 20-day hindcasts), and timestep (for the 2-day hindcasts). With data from between 12 and 27 models, depending upon the experiment, this data set is likely more valuable than the Coupled Model Intercomparison Project Phase-5 (CMIP-5) for many applications beyond the MJO, including analysis of monsoons and tropical-extratropical teleconnections.

Please publicize this data set widely and consider using it in your own research.

Young Hydrologic Society

Wouter Berghuijs

Ph.D. Student in Hydrology at the University of Bristol, UK; Chair of the Young Hydrologic Society

During the 2012 European Geosciences Union (EGU) General Assembly in Vienna, several hydrology students observed that there was no organizational structure for the involvement of early career researchers (ECR) in the EGU Division of Hydrological Sciences (HS), and that there were few ECRs actively involved within the Division. It was clear that with about 30% of the membership of the HS Division being classified as early career scientists and making up over 50% of the General Assembly participants, there was enormous potential to increase their involvement. This would not only enhance their own conference experience, but also improve their contribution to the HS Division and the hydrological sciences community as a whole. This was the key motivation behind the establishment of the Young Hydrologic Society (YHS).

YHS is an initiative to engage early career hydrologists from across the globe and aspires to function as an umbrella organization for the many academic, professional and social aspects important to these scientists. The YHS defines "young hydrologist" as anyone who can benefit from or contribute to the Society. The focus of YHS is on early career (M.Sc., Ph.D., Post-Doc) hydrological scientific community, but is not strictly limited to this.

The YHS organizing committee is composed of volunteers from multiple universities spanning three continents (and counting). To ensure that activities represent the broader opinion of other members in hydrology, YHS organizes an annual public meeting at both the American Geophysical Union (AGU) Fall Meeting and the EGU General Assembly, where early career hydrologists are invited to evaluate objectives, define goals and create opportunities for young scientists to get involved. Based upon these meetings, five objectives were established for YHS.

1. **Connect to** hydrologists early in their careers,
2. **Organize events** to enhance the professional development of early career hydrologists,
3. **Provide a central information platform** for early career hydrologists,
4. **Create awareness** of current and future research topics within hydrology, and
5. **Reform hydrological science** towards more involvement of early career hydrologists.

To achieve these goals, YHS created a website to provide notification of upcoming conferences, workshops, events, free online lectures and other relevant information. YHS also has a rich social media platform using LinkedIn, Facebook and Twitter to keep all YHS members and followers digitally connected.

Additionally, the YHS organizes sessions, short courses and social events at the AGU Fall Meeting and the EGU General Assembly. A recent example includes the first AGU Student and Early Career Scientist Conference where 100 young scientists gathered on the Sunday before the Fall Meeting to meet peers, participate in workshops to improve their academic skills and lay the foundations for lifelong academic friendships. At the 2015 EGU General Assembly, several short courses were organized addressing paper writing skills, hydro-informatics, teaching and current and future directions in evaporation research. A session was organized to provide early career scientists the opportunity to give a 5-minute TED-like presentation on their future vision of water sciences. In addition, at the 2015 Joint AGU and EGU Assembly, an Early Career Hydrologist Night was held to discuss current hot hydrologic issues with experts.

YHS scientists at the AGU Fall Meeting in 2014.

YHS is always looking for new members to help organize events, develop new ideas and enable YHS to expand to more parts of the world. YHS consists of a board that manages all YHS-related activities, working groups responsible for organizing specific YHS events and taskforces responsible for specific tasks, such as managing social media channels. Country representatives function as the link between national hydrological organizations and the YHS. Joining the YHS organizing team does not have to be very time-consuming, but can be very rewarding as it is a great way to start working with colleagues from all around the world.

As the YHS is in its infancy, most of the activities have been focused around the EGU and AGU meetings; however, YHS is working to expand to other organizations and regions of the world. If you are interested in being involved in YHS or have suggestions or general inquiries, please send us an e-mail. Get connected, get inspired and get involved!

Website:	www.younghs.com
Twitter:	@YoungHydrology
Facebook:	Young Hydrologic Society
LinkedIn:	Young Hydrologic Society
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Terrestrial Water Storage Variations in the Western United States Estimated from GPS Loading Deformation

Yuning Fu, Donald F. Argus, Felix W. Landerer, David N. Wiese, and Michael M. Watkins

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Monitoring quantitatively and in near real-time variations of global and local terrestrial water storage is crucial for informed water resource management and water-related policies. In the western United States (Washington, Oregon and California), water resources available for consumption and agricultural irrigation rely heavily on seasonal hydrological precipitation, including rainwater and snow during the fall and winter seasons. Near real-time water storage information is necessary for water managers and policy makers to evaluate potential water-related hazards, such as the current severe drought in southern California (Famiglietti, 2014).

Hydrological assimilation models, such as the Global Land Data Assimilation System (GLDAS; Rodell et al., 2004) provide global and local terrestrial water storage modeling results. Modern spatial geodetic satellites have also been extensively applied to observe and infer surface water variations. Launched in 2002, the Gravity Recovery and Climate Experiment (GRACE) detects time-variable gravity change and can be used to infer hydrological surface mass changes at spatial scales of several hundred kilometers (Tapley et al., 2004; Watkins et al., 2015). Based upon Global Positioning System (GPS) multipath (reflected) signals and geometric relationships, terrestrial water change (e.g., snow depth and soil moisture) near the stations can be quantitatively estimated (Larsen and Small, 2013).

Here, we use the physical loading theory and loading displacements measured by GPS to calculate water mass variations in the western United States at monthly time scales. We will demonstrate that the dense GPS network has unique advantages for monitoring water resource changes and serves as an independent and complementary tool to other measurements.

GPS Measurement of Loading Deformation and Inversion Model

The crust of the Earth deforms due to the change of surface mass load in an elastic response (Farrell, 1972). Crustal deformation can be measured with millimeter accuracy using GPS. In the western U.S., there are more than 1000 continuous GPS stations, most of which belong to the Plate Boundary Observatory (PBO) Project (*http://pbo.unavco.org/*). Although PBO was originally designed to measure the tectonic plate boundary deformation, the dense network can also be used for hydrological applications (Borsa et al., 2014). In our study, we adopted the Jet Propulsion Laboratory (JPL) GPS daily solutions in precise point positioning mode (Zumberge et al., 1997) and processed these with the Global Navigation Satellite System (GNSS)-Inferred Positioning System and Orbit Analysis Simulation (GIPSY) software (Desai et al., 2011). Because we are interested in the loading deformation caused by hydrological surface water changes, we removed atmospheric loading effects from GPS measurements using the data and programs provided by the Global Geophysical Fluid Center (GGFC) (van Dam, 2010).

The inset in Figure 1 below shows the vertical elastic displacement due to a change of a uniform disc load with 1-m water height and 20-km radius. Green's functions were used based on the Preliminary Reference Earth Model (PREM; Dziewonski and Anderson, 1981). This can be considered a forward model describing how the crust deforms in an elastic response to surface loading variations.

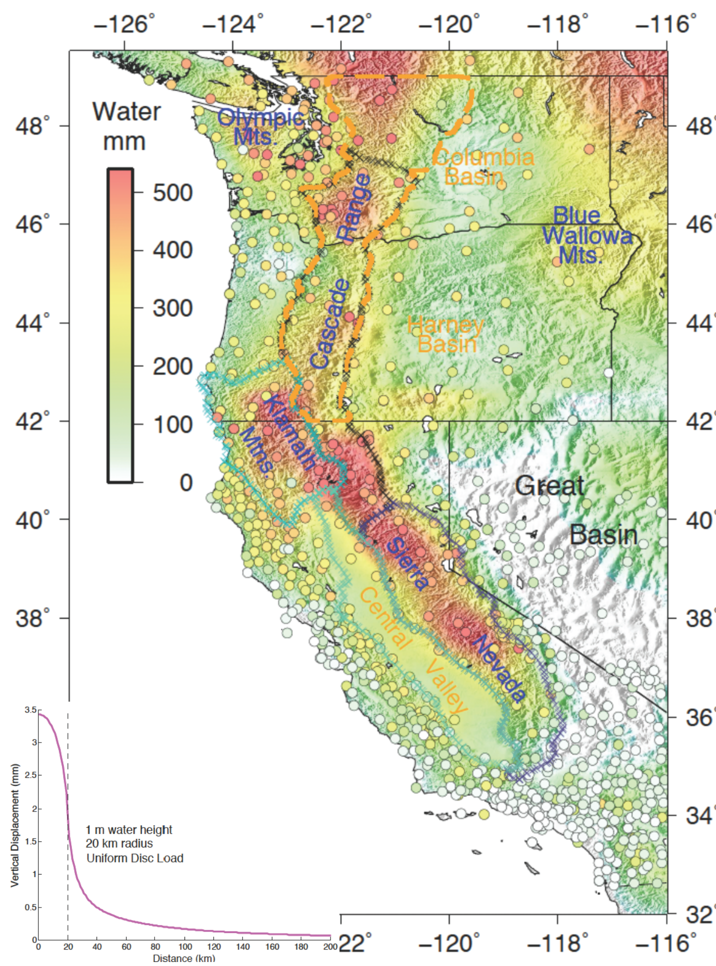

Figure 1. Seasonal water storage variations from October to April in Washington, Oregon and California. The circles represent GPS locations and seasonal displacements. Different physiographic provinces are also labeled for comparison.

To estimate or invert for terrestrial water mass changes from GPS-observed loading deformation, a damped least square inversion strategy was used to estimate the optimal fit to surface water mass variations. This minimizes the combination of Weighted-Residual Sum of Squares (WRSS) and a roughness parameter as shown in the equation below (Fu et al., 2015).

$$\underbrace{||W(Gx-b)||^2}_{Misfit(WRSS)} + \beta^2 \underbrace{||Lx||^2}_{Roughness} \rightarrow min$$

G represents the loading for Green's functions and *b* the GPS-measured vertical loading displacement. Laplacian smoothing (*L*) was applied to limit unrealistic water storage changes between neighboring grids. More details of the inversion strategy and synthetic tests are given in Fu et al., 2015.

GPS-Determined Water Storage Variations in the Western United States

We invert for two types of terrestrial water mass variations for Washington, Oregon and California: multi-year averaged seasonal water storage change, and monthly terrestrial water variations since 2006.

Figure 1 shows the GPS-determined multi-year averaged seasonal water storage change in Washington, Oregon and California. The results show the largest amplitudes of seasonal water change are located in the mountain regions—the Cascade Range, Olympic Mountains, Klamath Mountains and Sierra Nevada. The seasonal water change can be up to 0.5 m in equivalent water thickness. In the valley and basin areas, such as the Columbia Basin, Harney Basin and Great Basin, the seasonal water storage is much smaller. Our results demonstrate that the dense GPS network in the western United States accurately detects seasonal water loading variations between different physiographic provinces (Argus et al., 2014; Fu et al., 2015).

The monthly GPS height time series was used to infer the time-variable water storage changes to investigate variations at higher temporal resolution. The left panel in Figure 2 shows monthly terrestrial water mass variations in the Cascade Range, Klamath Mountains and Sierra Nevada inferred from the GPS monthly time series. In the Cascade Range, GPS results clearly record the previous drought period from 2008 to 2010, and a wet period from the beginning of 2011 to the end of 2012. In the Sierra Nevada, the current California drought with continuously decreasing water storage since 2011 is significant from GPS-inferred water change. GPS results also show a previous drought period from 2006 to 2009 and a wet period between 2010 and 2011 in the Sierra Nevadas.

The GPS-determined water change amounts were compared with the JPL GRACE monthly mass grid solutions (Figure 2, right panel) from the GRACE Tellus website (*http://grace.jpl.nasa.gov*). Its data processing algorithms are introduced in Swenson and Wahr (2006) and Landerer and Swenson (2012). Beginning in 2011, GRACE data have gaps because of a battery problem on one of the satellites. Several months of solutions are missing when gravity observations are not available. GPS-determined water storage change was used to fill in the water storage values for those months when GRACE observations were missing. Using the Cascade Range as an example; the red dots in the right panel of Figure 2 indicate the water mass for GRACE using GPS. Because GPS-determined water change is based upon actual observations, its estimation for those months without GRACE

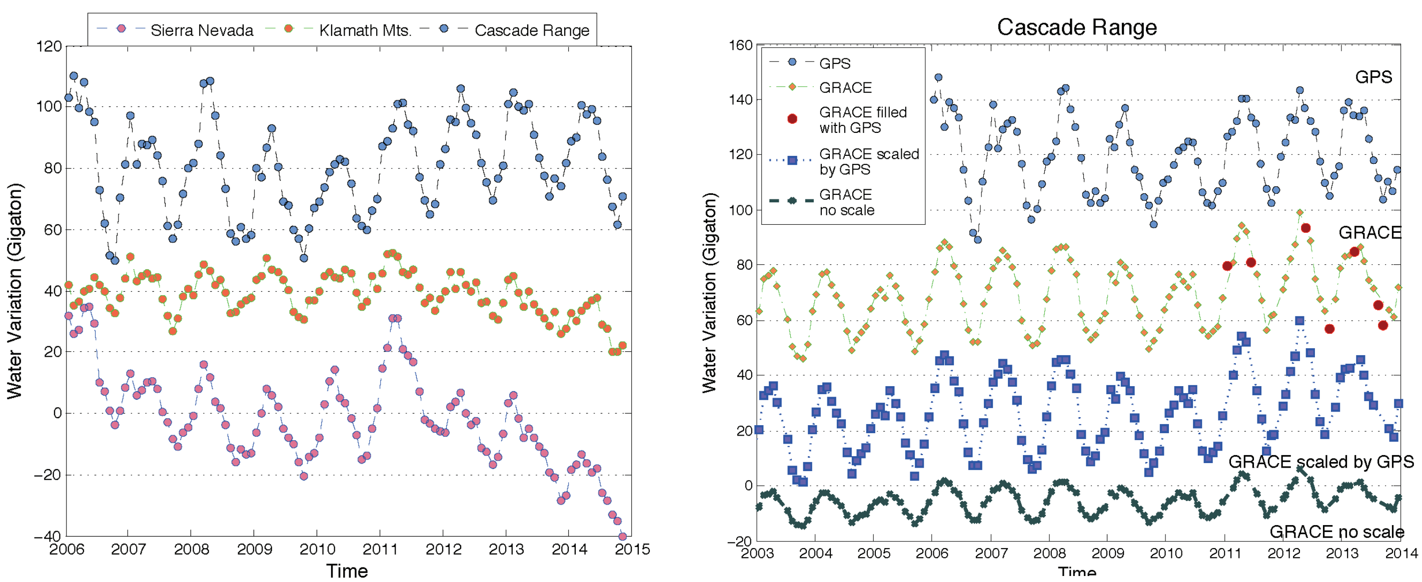

Figure 2. Left: GPS-determined water storage change within three mountain systems (Cascade Range, Klamath Mountains and Sierra Nevada) in the western United States. Right: Demonstration that GPS-determined water change can be used to fill GRACE solutions for the months when GRACE measurements are not available. The scaling factors for GRACE with GPS-inferred water mass change were also determined.

observations are more precise than a simple linear interpolation with neighboring months of GRACE data alone (Fu et al., 2015). There may also be a temporal gap between the current GRACE mission and future follow-on missions, and these results demonstrate how the measurements from dense GPS networks can potentially fill in future gaps when GRACE measurements might not be available.

To compensate for the damped signal during GRACE post-processing filter process, scientists usually apply a gain factor from an independent hydrology model to raw GRACE solutions (Landerer and Swenson, 2012). The method used by the authors to estimate surface water change with GPS-measured loading deformation fully resolves spatial scales up to approximately 70 km. The scaling factor for GRACE resolution can be determined by minimizing the difference between the GPS derived water series and the GRACE water series. Figure 2 (right panel) shows the water storage change in the Cascade Range using the GPS inversion result, the GRACE original solution without scaling and the GRACE solutions scaled with GPS-determined water change. The comparison indicates that the GPS-scaled GRACE solutions are consistent with the solutions scaled by the hydrological model-based gain factors from Landerer and Swenson (2012). Therefore, it can be concluded that GPS, as an independent observation, can provide accurate, observation-based scaling factors to GRACE observations for regions with dense enough GPS networks.

Discussions and Conclusions

With a dense GPS network, water storage variations can be quickly evaluated from GPS-measured loading deformation. Using rapid orbit and clock products, GPS positions can be derived with only 1-day latency. Thus, GPS-determined terrestrial water changes are effectively available in near real time. Water-related management and policy decisions need such timely information for efficient and informed water resource management. In comparison, the current GRACE data processing standard has 2–3 months of data latency for its monthly solutions. In addition to this timing advantage, the GPS-determined water variations can fill current and future temporal gaps when GRACE observations might not be available, and determine the scaling factors for GRACE measurements at smaller spatial scales. Those unique advantages of GPS make it a promising tool to monitor hydrological water variations globally and locally when more dense GPS networks are deployed around the world in the near future. The methods introduced here may be applied to North America, Europe and Japan, where dense GPS networks already exist.

In conclusion, these studies demonstrate that GPS, as an independent measurement, can provide accurate estimations of water storage variations by inverting the crustal loading deformation. GPS-determined water storage is complementary to GRACE time-variable gravity measurements and hydrological models for assessing water resources. GPS-inferred terrestrial water mass variation can be quickly performed in near real time, and used to fill the temporal gap between the GRACE mission and future follow-on missions, and to determine scaling factors for GRACE solutions. The authors are optimistic that GPS-wide usage will be applied to monitor water resource variations around the world in the near future.

Acknowledgments: The authors thank Graeme Stephens, James Famiglietti, and Jason Evans for their helpful discussions. The research described in this newsletter was carried out at the JPL California Institute of Technology and sponsored by the National Aeronautics and Space Administration.

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YOUNG EARTH SYSTEM SCIENTISTS **community**

Sebastian Sonntag

Postdoc Researcher, Max-Planck-Institut für Meteorologie, Hamburg, Germany; YESS Steering Committee

The Young Earth System Scientists (YESS) community is a global network of early career scientists that aims to connect young researchers around the world, moving Earth system science beyond its current boundaries. YESS is structured as an integrated but interdisciplinary community within the Earth system sciences, strengthening the joint efforts of various natural, social and economic sciences to address questions of Earth system components and their interactions with one another.

The YESS community is built from the bottom up to enhance collaborations both locally and globally, simplify the dissemination of scientific results and support early career scientists in their individual career development. To accomplish this, YESS specifically tries to unify ongoing and planned early career communities within the World Weather Research Programme, the World Climate Research Programme, and the Global Atmosphere Watch.

The YESS community is

- an independent, self-contained communication platform for young Earth system scientists;
- currently the only unified, international and interdisciplinary early career Earth system researchers network; and it
- introduces and strengthens collaboration across institutional and local boundaries, spreading initiatives and events, and providing opportunities for direct personal contact at meetings and conferences.

The YESS community web page at *www.yess-community.org* is:

- a non-public, moderated online community network;
- open and free for interested users;
- a network platform that enables registered users to create a custom profile and to communicate, network and interact with other users of the community; and
- a platform that gives members access to the members directory, forums, and (local or topic) groups.

If you are a Masters or Ph.D. student or a Postdoc and are interested in a network that reaches out beyond your specific discipline, join YESS! E-mail us at: *contact@yess-community.org*.

Clouds, Circulation and Climate Sensitivity Grand Challenge and GEWEX

Graeme Stephens[1], Sandrine Bony[2], and Bjorn Stevens[3]

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How sensitive is the Earth's surface temperature to radiative forcing? This question is central to the World Climate Research Programme Grand Science Challenge on Clouds, Circulation and Climate Sensitivity (referred to hereafter as the "Climate Grand Challenge or GC"). It has been understood for many years how the answer to this question is tied to understanding the way clouds evolve in response to subtle shifts in the atmospheric circulation. If we have appreciated this connection for some time, then why hasn't there been more progress? This is a question touched on in the recent Bony et al. (2015) review of the Climate GC. The answer in part could be because research has generally been fragmented with efforts to understand clouds and convective processes being developed separately from efforts to understand larger-scale circulations. A clear but surprising example of the fragmented nature of how the science has evolved over the years is evident in how clouds and precipitation have traditionally been studied, each viewed as entirely separate entities being addressed by separate communities with different and generally unconnected ways of observing them. Another example is found in the case of moist convection that has developed in parameterizations for large-scale models in a way that is often abstracted from the cloud processes that are so obviously important for understanding the role of convection in climate. These two examples, in fact, are highly relevant to the questions being posed under the Climate GC.

The Climate GC comes at an opportune time. The situation is changing in part due to technological progress that has tremendously increased our capacity to observe and simulate the climate system, and in part due to conceptual advances that together offer the opportunity to advance understanding of how small-scale convective processes influence the larger-scale climate system. Bony et al. (2015) argue that by recognizing these opportunities, progress in climate change assessments could be accelerated through the development and testing of a small number of hypotheses, or story lines, that link changes in regional patterns, extremes, climate sensitivity and other important features of climate in a self-consistent way. They organize their grand challenge around four questions. By focusing research on the development and testing of story lines around these four specific questions, a more comprehensive analysis will be possible, one in which the integration of observations, evidence obtained from a hierarchy of models, and physical understanding will advance knowledge much more efficiently than would the consideration of particular lines of evidence in isolation. These questions and why they are opportune are briefly summarized below.

What controls the position, strength and variability of storm tracks?

Although our understanding of extra-tropical storms has been largely based on dry dynamics, the roles of the large-scale coupling of clouds with storm tracks is now beginning to be appreciated. Approximately half of the poleward transport of energy within storm tracks is accomplished by the latent heat component, meaning moisture is vital in setting the temperature gradients upon which storms grow. The release of latent heat within the warm sector of storms and in frontal regions provides an additional energy source for cyclogenesis. It is now clear that as the clouds embedded within the storm tracks shift, there are systematic implications for the radiation budget and its influence on the temperature gradients that give rise to the storms in the first place. Understanding how storm-tracks may change in the future may well depend upon understanding the role of clouds and precipitation within them.

What controls the position, strength and variability of the tropical rain belts?

A number of papers have recently addressed this question, exploring interactions on various scales. Mesoscale convective circulations appear to influence the poleward extent of the monsoon in ways that are just starting to be understood, and planetary scale circulations connect the rain belts to processes in distant extra-tropical locations. Newly developed energetic frameworks have proven to be a useful way to understand these connections and clouds play a central role in this understanding.

What role does convection play in cloud feedbacks?

Convection influences the climate system in profound ways. Deep convection is the source of of upper tropospheric moisture and high clouds in the tropics, both with significant effects on climate energetics and the hydrological cycle. The relevance of this question is illustrated in the way models exhibit a large degree of freedom in their prediction of upper-level cloud cover responses, and in their representation of shallow convective mixing, which appears to determine the strength of their low-cloud feedbacks, as a function of the representation of convective circulations. Hence, the authors argue that understanding clouds is intimately linked to an understanding of convection.

What role does convective aggregation play in climate?

The propensity of convection to aggregate and organize into larger entities has long been related to the variability of weather and to the occurrence of extreme rainfall events. In the tropics, the Madden Julian Oscillation and monsoonal storm systems are an aggregate of convective processes organized into mesoscale convective systems (MCS) that cluster into a large-scale envelope of storm activity. The MCS are also a major mode of storminess over the midwest of the North American and the West African Monsoon, producing much of the severe weather there. In the US this includes tornadoes and hail in spring and 30–70% of the warm season rainfall. The idea that the organization of moist convection might play a role in the dynamics of the climate system is not a new one but the importance of MCS on the climate system as a whole is now being realized.

GEWEX connects to the Climate GC in a number of ways. The projects within the GEWEX Panels provide some of the scientific foundation for answering the questions raised by the Climate GC. Many of the high-resolution modeling studies that the GC argues can be leveraged to advance the science, were born out of the Global Atmospheric System Studies (GASS) Panel and its predecessor projects, which inherently and increasingly address the connections between convection and the larger scale environment. The cloud and precipitation data projects of the GEWEX Data and Assessments Panel (GDAP) and the GEWEX Hydroclimatology Panel (GHP), the land-atmosphere interaction studies of the Global Land/Atmosphere System Study (GLASS) and feedbacks on "rain bands," and the high resolution model activities that are developing more and more under GEWEX, all connect to this GC in elementary ways. If we consider a parallel question about the hydrological sensitivity of the climate system in the form "**How sensitive is the Earth's hydrological cycle to radiative forcing?**"as one that is overarching for the Water Availability GC, then the relationship to the Climate GC becomes even sharper with the questions posed being also relevant to understanding the Earth's hydrological response to warming.

Hot towers and cumulus fields. Photo Credit: ©iStock.com/langotastic.

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New GEWEX Crosscut Project Addresses Mountain Snow and Ice Hydrology and Atmospheric Interactions

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Mountains receive and produce a disproportionately large fraction of global precipitation and streamflow that contributes to floods and essential water supplies for vast sub-humid downstream areas occupied by at least 50% of humanity. Research in alpine catchments is complicated by data scarcity, as there are only a few well equipped research catchments in the world. As a result, snow and ice hydrological processes in these regions are not completely understood, are extremely diverse, and are rarely represented appropriately in hydrological and land-surface models. There is an international need to improve the understanding and modeling of snow and ice hydrological processes in alpine catchments, and these improvements must be supported through careful observations. Due to the limited number of and geographical dispersion of alpine research catchments, there has been relatively little intercomparison of high mountain processes and hydrological behavior throughout the world.

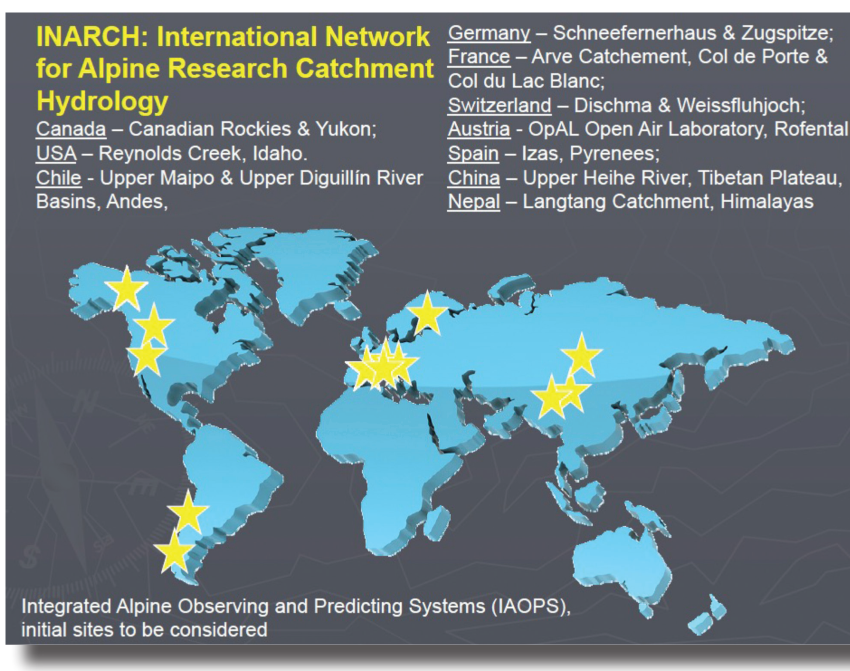
These concerns prompted 25 scientists operating 14 research catchments around the world to develop the International Network for Alpine Research Catchment Hydrology (INARCH). This new GEWEX Hydroclimatology Panel (GHP) Crosscutting Project focuses on alpine catchments that are well equipped to measure snow and ice hydrology. Information obtained from this initiative will be used to investigate the effects of mountain snowpacks and glaciers on water supply and to study variations in energy and water exchange in different high-altitude regions.

A number of questions regarding alpine catchments were raised during the GHP meeting held in The Hague in July 2014 that led to the creation of INARCH. These include: (i) what is the best methodology for measuring snow and ice hydrology in various alpine regions? (ii) how do land-surface energy and water exchanges differ in various high mountain regions of the Earth? and (iii) what improvements to high mountain hydrological predictability are possible in various alpine regions through improved process physics, representation of spatial variability and incorporation of ground and remote observations? To address these questions, the overall objective of INARCH is to better understand alpine cold regions hydrological processes, improve their prediction, and find consistent measurement strategies. To achieve this objective it is necessary to develop transferable and validated model schemes of varying complexity to support research in data sparse mountain areas.

Surface based data requirements for this project will primarily be met by detailed, openly-available meteorological and hydrological observational archives from long-term research catchments with high temporal resolution (at least 5 years of continuous data with hourly sampling intervals for meteorological data, daily precipitation and streamflow and regular snow and/or glacier mass balance surveys) in selected heavily-instrumented alpine regions, atmospheric model reanalyses, and downscaled climate model outputs.

The methodology to be used by INARCH will include: (i) comparing instrumentation best practices; (ii) suggesting improvements in instrumentation; (iii) developing reliable alpine data sets for model testing and numerical experiments; (iv) conducting process algorithm intercomparisons; (v) conducting model uncertainty and climate sensitivity analyses; (vi) demonstrating improvements to model predictability; (vii) evaluating different downscaling schemes; (viii) fostering research and development for future observing schemes; and (ix) facilitating education and training programs to build and enhance science capacity and communicate the science results to the public. One of the ways that INARCH will build capacity around the world is by contributing to the UNESCO International Hydrological Programme.

The first INARCH meeting will be held in Canada on 22–23 October 2015. In addition, a session on "Improved understanding and prediction of mountain hydrology through alpine research catchments" is planned for the American Geophysical Union Fall Meeting in San Francisco. Additional information about INARCH is available at: *www.usask.ca/inarch/*.



Location of some initial possible INARCH sites.

Workshop on the Aerosols-Clouds-Precipitation and Climate (ACPC) Initiative

New York, New York, USA
8–10 April 2015

Johannes Quaas[1], Daniel Rosenfeld[2], Ann Fridlind[3], and Robert Wood[4]

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During Phase 1 (2007–2012), the joint GEWEX/Integrated Land Ecosystem Atmosphere Processes Study (iLEAPS) Aerosols-Clouds-Precipitation and Climate (ACPC) initiative demonstrated the diverse effects that aerosols exert on precipitation (Rosenfeld et al., 2008). Stevens and Feingold (2009) argued that in many cases cloud-precipitation systems tend to buffer or dampen the amplitude of the aerosol effects. ACPC then reviewed global observations related to aerosol-cloud-precipitation-climate interactions (Rosenfeld at al., 2014) and how a field campaign could be designed to go beyond the existing data sets in fully characterizing the energy and water budgets for varying aerosol conditions.

The ACPC initiative started its second phase in late 2013. The first workshop in this phase was held on 8–10 April 2015 at the NASA Goddard Institute for Space Studies (GISS) in New York to discuss such a possible future field campaign design and potential roadmaps towards it. The focus was on the possibilities of exploiting high-resolution modeling with detailed microphysics to assess observational requirements and opportunities for such experiments.

Presentations and discussions reviewed the experience with past field experiments on shallow and deep convective clouds. The general consensus of the group is that the aim of observing the complete energy and water budget, including lateral fluxes, was too ambitious. As an example, the experience from the Tropical Western Pacific (TWP)-International Cloud Experiment (ICE) observing deep convective clouds showed an accuracy of precipitation observations of ±25% (Fridlind et al., 2012) that is to be contrasted with precipitation responses of ±9% for large aerosol perturbations in model sensitivity studies for the same case (Lee and Feingold, 2010). New capabilities, in particular from polarimetric radar networks, were discussed as highly promising data sources to analyze specific cloud microphysical and dynamical processes in convective clouds. Radiation observations were highlighted as particularly useful information for aerosol-cloud interactions for shallow clouds. The workshop noted that satellite observations likely offered the tightest constraints on any energy budget terms (at top of atmosphere), in addition to providing the large-scale context of a field experiment.

Several approaches to exploit aerosol variability were presented, including the exploitation of spatial gradients, such as was done in the Variability in the American Monsoon Systems (VAMOS) Ocean-Cloud-Atmosphere-Land Study (VOCALS), of the seasonal cycle (e.g., aerosol precursors in the southern oceans) of sporadic volcanic sources or of ship tracks.

Eight modeling groups from France, Germany, the United Kingdom and the United States reported on their experiences with large-domain long-term cloud-resolving and cloud-system-resolving simulations of aerosol-cloud-precipitation interactions. Some of the modeling groups emphasized the need to simulate domains that are sufficiently large and periods sufficiently long to allow the full buffering potential of the system to evolve. It was also noted that aerosols or cloud condensation and ice nuclei should be treated interactively with sources, processing and sinks for a realistic simulation of the dynamical system. Experience presented at the workshop based on sensitivity studies with single models, and on past model intercomparison studies (e.g., Wyant et al., 2015), showed the wide range in responses of clouds and precipitation to regional aerosol perturbations that highlighted the current uncertainty in the interactions.

The workshop participants agreed to proceed with two modeling exercises, one focusing on deep convective clouds, and the other focusing on stratocumulus clouds. The objective of these exercises is to simulate a specific cloud regime with large-domain, cloud-resolving models in order to characterize signal-to-noise ratios for various observables for given aerosol perturbations. The goal of a series of such studies is the definition of one or more experiments and the required observing systems to clearly identify signatures of aerosol-cloud-precipitation interactions given expected aerosol perturbations.

The deep convective study will address clouds as observed during the NASA Studies of Emissions, Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC4RS) and Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality (Discover-AQ) campaigns in autumn 2013 near Houston, Texas. In both campaigns, deep clouds are triggered repeatedly by the sea breeze and are influenced by local pollution, which has been well characterized in Discover-AQ measurements. The shallow cloud study will simulate the VOCALS field experiment period using only natural aerosols in one, and the full aerosol emissions in another simulation. In both cases, the terms necessary to characterize the energy and water cycles will be diagnosed from the models, in addition to key cloud microphysical, aerosol, precipitation and radiation quantities. The simulations will also be used to explore the extent to which correlations between observed aerosol and cloud properties in the current climate can be used to infer the sensitivity of clouds to aerosols under climate change. The simulations will be evaluated with the existing observations, and multi-model participation will allow assessment of uncertainties and sensitivities.

The planned modeling exercise is intended to be coordinated with the GEWEX Global Atmospheric System Studies (GASS) Panel and the World Meteorological Organization cloud modeling workshops. A follow-up workshop is planned in Oxford on 13–15 April 2016, where the first results will be discussed and next steps planned. Interested scientists are welcome to join the initiative, especially if they are working with cloud-resolving models or regional climate models at high resolution that explicitly simulate aerosol-cloud-precipitation interactions, but equally if interested in contributing observational expertise.

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GEWEX/WCRP Calendar

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

20–22 May 2015—GLASS Panel Meeting and Joint GLASS/GABLS DICE Workshop—Toulouse, France.

25–29 May 2015—World Water Congress XV—Edinburgh, Scotland.

14–19 June 2015—Chapman Conference on Evolution of the Asian Monsoon and its Impact on Landscape, Environment and Society—Hong Kong, China.

15–26 June 2015—1st WCRP Summer School on Climate Model Development: Atmospheric Moist Processes—Hamburg, Germany.

22–24 June 2015—WWRP/WCRP Workshop on Subseasonal to Seasonal Predictability of Monsoons—Jeju, Republic of Korea.

22 June–2 July 2015—26th IUGG General Assembly 2015—Prague, Czech Republic.

29–30 June 2015—Workshop on Uncertainties at 183 GHz—University Pierre et Marie Curie, Paris, France.

29 June–2 July 2015—Workshop on Input Observations for Reanalysis—Reading, United Kingdom.

2–3 July 2015—4th Session of the WCRP Data Advisory Council—Reading, United Kingdom.

7–10 July 2015—Our Common Future with Climate Change—Paris, France.

3–6 August 2015—US CLIVAR Summit—Tucson, Arizona, USA.

23–28 August 2015—14th International Swiss Climate Summer School–Extreme Events and Climate—Ascona, Switzerland.

24–28 August 2015—SPARC Workshop on Storm Tracks—Grindelwald, Switzerland.

7–11 September 2015—SOLAS Open Science Conference—Paris, France.

15–17 September 2015—3rd Space for Hydrology Workshop—ESA-ESRIN, Frascati, Italy.

16–18 September 2015—NCAS Climate Modeling Summer School 2015—Cambridge, England.

21–25 September 2015—9th HyMeX Workshop—Mykonos, Greece.

29 September–2 October 2015—Annual GDAP Meeting—Xiamen, China.

5–9 October 2015—11th International Conference on Southern Hemisphere Meteorology and Oceanography—Santiago, Chile.

13–16 October 2015—International Conference on Water Resources Assessment and Seasonal Prediction—Koblenz, Germany.

20–23 October 2015—Earth Observations for Water Cycle Science—ESA-ESRIN, Frascati, Italy.

20–23 October 2015—WCRP/FP7 EMBRACE Workshop on CMIP Model and Analysis and Scientific Plans for EMIP5—Dubrovnik, Croatia.

4–5 November 2015—GEWEX Water Vapor Assessment Workshop—Madison, Wisconsin.

9–11 November 2015—GEWEX Workshop on the Climate System of the Pannonian Basin—Osijek, Croatia.

17–19 November 2015—International Conference on Water and Energy Cycles in the Tropics—Paris, France.

25–29 January 2016—28th Session of the GEWEX SSG—Zurich, Switzerland.

10–13 May 2016—Earth Observation and Cryosphere Science—ESA-ESRIN, Frascati, Italy.

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