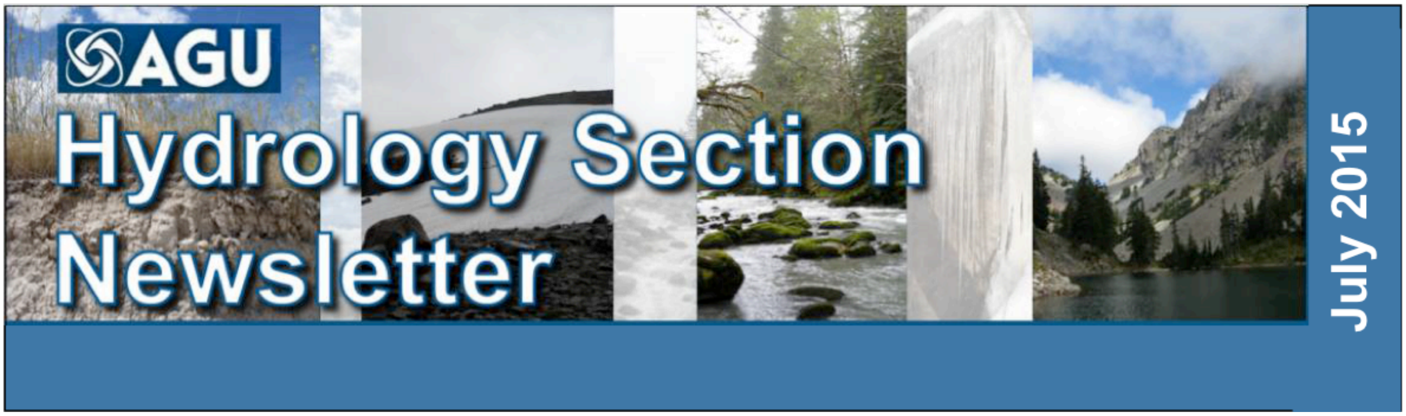

From the Section President

Efi Foufoula-Georgiou (University of Minnesota)

Dear colleagues, dear friends,

It is tempting to start the July newsletter by referring to the beginning of the summer. However, the global reach of our section reminds me that it is not summer for all of us! So, in whichever season this letter finds you, I hope you are well and spirited.

Since I took office as the president of our section 6 months ago, it has been busy not only for me but for the many volunteers who make our section work. We are collectively making good progress on the following priorities: (1) rewarding excellence and establishing a new midcareer award; (2) strategizing on increasing the scope and visibility of our section and improving our Fall Meeting experience; (3) mentoring our young researchers and expanding/rewarding their activities within AGU and beyond; and (4) interfacing with AGU leadership to ensure that our sections' needs are heard and honored. Please read below more details on these four initiatives.

New mid-career award: I am happy to report that the AGU Honors and Awards committee has approved our proposal for the *"Paul A. Witherspoon Mid-career Lecture in Hydrologic Sciences."* This award will bridge the HS Early Career Award (up to 6 years since Ph.D.) and the HS Award and Langbein lecture (reserved for senior scientists).

2015 Hydrology Section Awardees

The Hydrology Section has just announced our 2015 awardees. Please join me in congratulating:

Walter Langbein Lecturer:
Tissa Illangasekare, Colorado School of Mines

Hydrologic Sciences Award:
Dara Entekhabi, Massachusetts Institute of Technology

Hydrologic Sciences Early Career Award:
Tom Gleeson, University of Victoria

Horton Research Grant Recipients:
Laura Stevens, Massachusetts Institute of Technology
Emily Voytek, Colorado School of Mines
Adam Wlostowski, Colorado State University

The goal of the "Paul A. Witherspoon Midcareer Lecture in Hydrologic Sciences" is to recognize outstanding contributions in the hydrologic sciences by a midcareer scientist (within 10 to 20 years post-Ph.D. degree), including the awardee's research impact, innovative interdisciplinary research and application to societally important problems, and inspired and dedicated mentoring of young scientists, and to acknowledge that the awardee shows exceptional promise for continued leadership in hydrologic sciences. Nominations will begin with the 2016 cycle.

Paul A. Witherspoon (1919–2012), University of California, Berkeley, and later Lawrence Berkeley National Laboratory, made significant contributions to the understanding of flow of fluids in porous media and fractured rock, and he applied his findings to a diverse set of societally important issues, including the development of geothermal energy, use of underground gas storage, and siting and design of nuclear waste disposal facilities. He was an inspirational mentor to a large number of young researchers who went on to develop successful research careers in their own right. As expressed in his obituary (Eos, 31 July 2012) "to enter Paul's orbit was to experience a stimulating mix of high intelligence, deep curiosity, and love of life."

Improving Section visibility and Fall Meeting experience: A new Ad Hoc Committee for Fall Meeting Improvement was formed (President-Elect Jeff McDonnell, chair, Barbara Bekins, Kelly Caylor, Irena Creed, Charlie Luce, and Naomi Tague) to examine strategies and best practices to instigate more integrative and comprehensive sessions that avoid overlap and offer the opportunity for a larger part of our community to be together, exchange ideas, and witness the breadth and depth of our research. Please read their report and provide feedback. The HS participation in Fall Meeting is healthy and diverse, and I encourage you to read the report of Hydrology Section Program Committee Chair Barbara Bekins and previous chair Charlie Luce. I take this opportunity to thank them both for all their hard work on behalf of our section.

Mentoring Hydrology Section young researchers: Please see the article by Tim van Emmerik, chair of the newly established Hydrology Section Student Subcommittee. Read about their incredibly rich portfolio of activities and aspirations, including the trend-setting pre-AGU Student conference, majestic Pop-Up sessions now adopted within other sections, and social media activities, and learn how to become an active contributor to all that is happening to redefine how young scientists contribute to and shape the future of our science. Also, please read the article by our section secretary, Terri Hogue. Judging and rewarding the excellent science of our students during Fall Meeting is very important but not easy. Terri is leading this effort superbly, with the help of many volunteers. Still, we need more judges, so please make sure you volunteer for this activity—drop a note to Terri about your willingness to help.

More support from AGU central: I am happy to report that following 2 years of active discussions and voicing our concerns to AGU leadership regarding the necessity to provide more support for section activities, the AGU Finance Committee endorsed the following changes as of 2015: increasing the funding from $20 to $50 per attendee for one section networking event at the AGU Fall meeting and approving an additional $5,000 to support student/early career travel grants and/or other awards. We thank them for this!

For our section, I took the liberty of making the Hydrology luncheon free for students (hurray!) and charging $20/person for nonstudent members (still cheaper than last year, so please make a donation directly to our section—see link later). I also increased the capacity from 300 tickets to 400 (150 reserved for students, as they disappeared quickly last year).

Our main journal, *Water Resources Research*, is doing great, and I encourage you to read the report of the *WRR* editors (Alberto Montanari, EIC, Jean Bahr, Günter Blöschl, Ximing Cai, Scott Mackay, Anna Michalak, and Harihar Rajaram, editors). The *WRR* 50th anniversary volume will be out soon and ready to be celebrated at the 2015 Fall Meeting. Some of our technical committees use our newsletter to report major events and perspectives, and I thank Alexandra Konings and Erika Podest for contributing an article on the SMAP mission, which was launched on 31 January 2015. Lots of exciting challenges and opportunities for hydrology.

I congratulate once more the 2014 awardees and thank AGU Fellows Taikan Oki and Ana Barros, the Robert Horton Medalist Jim Shuttleworth, and the Hydrologic Sciences Early Career Awardee Stefano Manzoni for offering, in this newsletter, their perspectives on building a successful career, pursuing hard problems, and the opportunities and challenges that lie ahead.

Finally, please join me in congratulating our 2015 section awardees: Dara Entekhabi (Hydrologic Sciences Award); Tom Gleeson (Hydrologic Sciences Early Career Award); Tissa Illangasekare (Walter Langbein Lecture); and Laura Stevens, Emily Voytek, and Adam Wlostowski (Horton Research Grant Recipients). It takes a lot of effort to nominate, support via letters, and select via committee deliberations our awardees, and I thank all of those involved. We need more nominations for all of our awards, and the ad hoc committee on nominations (Eric Wood, chair) is there to be presented with names that are worth seeking nominations for.

I am sad to report the death of a well-known water resources engineer whose book has influenced two generations of hydrologists. Professor Joseph Franzini of Stanford University died at the age of 94, and his family and friends sent me an obituary, which I include in this newsletter. His family called him "a man of simplicity and common sense, dignity, and family devotion"—for our community, he was also "a man of dignity and devotion to the profession of hydrology bridging superbly the path between science and practice."

I look forward to seeing all of you in San Francisco in December. Please submit your abstract if you have not done so already—the deadline is 5 August 2015. Also, please consider making a donation to our section (direct link: https://giving.agu.org/campaign/hydrology-section-fund/) to allow funding more of our student activities and section events.

I thank Anthony Longjas at the University of Minnesota for helping me with the newsletter production.

Best regards to all,
Efi

Report of the Ad Hoc Committee for Fall Meeting Improvements

Jeff McDonnell (Chair), Barbara Bekins, Kelly Caylor, Irena Creed, Charlie Luce, and Naomi Tague

AGU Fall Meeting has been a scientific institution for nearly 50 years. The past 25 years have seen explosive growth, with the 2015 meeting attracting nearly 24,000 attendees. While these statistics are a telling endorsement of the meeting's success, the size and scope of AGU Fall Meeting are now its best and worst features. For the Hydrology Section (HS), this problem is especially acute given our size and dominance within the Union. This short report outlines the discussions of an ad hoc committee charged by our section president with examining AGU Fall Meeting and, specifically, ideas and proposed actions for improvement of the Fall Meeting experience. We list here a set of ideas for HS session development and best practices for session approval and curation.

The status quo: About 6 years ago, AGU adopted the open submission processes. This now means that session proposals are no longer vetted through a technical committee (TC). Anyone now has a right to submit a session proposal. Over 150 such proposals were received last year. All were accepted in some way, shape, or form to ultimately define the 125 sessions put on by HS in 2014. The Program Committee (PC) now has the unenviable task of forced mergers and session reductions. This is a problem because it is nearly impossible for the PC to do all this. With a limited membership, they cannot have in-depth knowledge of the diversity of HS subtopics. Thus, it is challenging for the committee to identify overlap or areas where mergers may or may not make sense. Given these limitations, and in order to be equitable, the PC tries to accept as many session proposals as possible, leading to a very large number of sessions that are often poorly attended simply due to the multiplicity of concurrent offerings. Meanwhile, the TCs spend almost all of their time during AGU Fall Meeting discussing sessions for the next Fall Meeting, but the open submission process undermines any thoughtful session coordination. Consequently, the TCs feel like they are not part of the decision-making process. They are asked to be reactive and forced into mergers they are often not comfortable with.

A new organizational process: Our ad hoc committee comprises the current PC chair, TC chairs, and members. Based on these experiences, we propose several improvements to the organization of Fall Meeting. First and foremost, we advocate better connection between the PC and the TCs. TC chairs should be empowered to be leaders in fostering discussion on emerging and frontier session topics. We need to be active in terms of how we curate sessions, creating some space for standing sessions, and fostering a community of people to discuss emerging and new ideas. HS has more sessions on a per capita basis than any other section of AGU. We need to reduce this. We should use TC meetings at Fall Meeting to identify frontier and emerging areas, and we should engage the PC in these meetings. These can be communicated to the PC at the TC chairs meeting. The PC and TC chairs should work together during session submissions and after session proposal submissions close to see what proposals could be merged and reparsed. We also advocate the creation and use of an online interactive tool where session ideas can be put forward by the TCs and others and can be discussed by the broader community. This would facilitate informal merging and collaboration prior to the submission of session proposals. For example, an interactive blog or Google group could be established, highlighted on the AGU hydrology website. In general, we recommend developing strategies to improved web-based communication between the TCs and the broader community.

Implementation of this new process: Implementation of the new organizational process has already begun. The PC will engage the TCs to create merged sessions that map to TC names/areas. Together, they will help decide if a session rejection should be considered, tabled until next year, or rejected outright. We need a firmer hand in all this so as not to be oversaturated with sessions (our attendees have a paradox of choice at present). The TCs can be the "memory" in the system of what has been proposed and well attended in previous years. Together, they can help define the right number of sessions overall for the best HS meeting experience. The HS will work with AGU and the TC to identify the best online platform (Google group, Interactive Blog) to support dialogue on session proposals.

Session "best practices": Going forward, session proponents should consider what type of session (foundational, frontier, or emerging) they are developing and think deeply on this as they develop their plan: (1) **Foundational Session:** Core sessions that reflect where the field is at. Our AGU bread and butter—these may or may not map to a TC theme. (2) F**rontier Session:** A lofty session goal where the session focuses on what we expect research needs to be in 5 or 10 years. (3) **Emerging Session:** Sessions that examine the interface between TC and sections. We would then advocate the following best practices for session organizers:

- To put thought into invited speakers (four max) who would best cover the session topic.
- To be mindful of gender bias and diversity, including international participants. The proportion of oral presentations by females should equal the proportion of female first author abstract submissions. The proportion of invited talks should be gender balanced.
- To ensure that no convener is a coauthor on any invited talk.
- To ensure that a convener does not give a talk in his/her session and, if he/she is a coauthor on an oral presentation, that this is limited to one.
- To agree that 33 abstracts are necessary to be allocated two oral slots (4 hours) to avoid microsplitting of sessions.
- For session proponents to work through the new web platform to generate interest in and shaping of the session between January and May.
- For each TC to think about sessions that they would like to curate and actively cultivate them with the broader community (via the HS Listserv and Google groups).

For the TC best practices, we propose that

- TCs organize in December, at AGU Fall Meeting, a true intertechnical chairs committee meeting (with the HS president, past president, and entire PC committee), a meeting that focuses on discussion of emerging areas warranting session development for the next Fall Meeting.
- TC Chairs and PC to have a November conference call to prepare for this, and then a January conference call to debrief on this.
- TC Chairs to take on a more active leadership role; to put TC ideas on their TC websites, etc., from January to May so that people know what is being developed and to give the larger community a chance to react to these ideas.

We hope that this brief report helps stimulate some changes in HS Fall meeting session development and best practices for session approval and curation. Our goal is to create sessions that are attractive to a larger number of people. We now look for feedback from the HS on these changes and how to improve further the Fall Meeting experience.

OSPA Updates and News

Terri Hogue, Colorado School of Mines, Hydrology Section Secretary

The Hydrology Section Outstanding Student Paper Awards (OSPA) is tasked with organizing both fall and spring meeting student judging and award selection. This requires working with the session liaisons and organizers to make sure that each student presentation

is assessed by three judges. The committee is led by the section secretary and four section members: Kolja Rotzoll (U.S. Geological Survey), Laurel Saito (University of Nevada, Reno), Newsha Ajami (Stanford University), and Tara Troy (Lehigh University). At the 2014 Fall Meeting, 477 student presentations were assessed, and the section gave out 15 awards. OSPA is extremely competitive; the average winning score this fall was 42.8 out of 45 (or 95%!). The Spring Joint Assembly had a total of 39 student presentations in Hydrology, with two awards given. In addition to high numerical scores, winning students must also have outstanding comments specific to their presentation. These written comments are weighted heavily, so please, when you judge a student, take a minute or two to add comments reflective of your scores and what stood out (good or bad) in the presentation. At least 85% of the students got scores from three judges, but we can do better. We had 27 judges who signed up but did not turn in scores. This year, we expect to judge over 500 presentations at the 2015 Fall Meeting, which will require 1500 assessments just in the Hydrology Section. Please take the time to provide feedback to our early career members by signing up to be an OSPA judge and helping us attain 100% judging and score submission. The OSPA team also helps organize and evaluate the Hydrology Section student travel grants that are submitted to AGU. We average around 150 applicants each year that require our review and selection of travel grant awards. If you are interested in helping on either OSPA or travel grant review, please get in touch! We value and appreciate the work our members do to support our students.

Report from the Hydrology Section Program Committee

Barbara Bekins and Charlie Luce

The main role of the Hydrology Section Program Committee is to perform session scheduling for all Hydrology sessions. The committee members are

Barbara Bekins (2015 chair), USGS; Bart Nijssen (2016 chair), University of Washington; and Casey Brown (2017 chair), University of Massachusetts. Each May, the current committee chair also votes on a few policy matters, most notably, proposed Union sessions, coorganized sessions, and SWIRL themes. Allocation of oral sessions and scheduling will begin this year when abstract submissions close on 5 August. The schedule will be finalized at the Program Committee meeting to be held at AGU Headquarters 9–11 September. In 2014, the number of abstract submissions required for at least one oral session was 18. Listed below are some other Hydrology Section statistics from the 2014 meeting.

- 2850 abstracts submitted (12.3% total AGU abstract submissions)
- 2836 remaining after moves to other sections
- 1941 posters and 895 oral presentations
- 109 room periods (2-hour blocks)
- Session proposals submitted: 154
- Unique sessions scheduled after mergers: 113
- Minimum number of abstracts required for oral session (# sessions): 18(1), 33(2), 51(3), 67(4)
- Sessions allocated at least one oral session: 71 (45:1, 18:2, 5:3, 3:4)
- Number of poster-only sessions: 42

In 2015, Hydrology Section received 144 session proposals. Before abstract submissions opened, these were reduced to 124, through mergers of similar session proposals. A strategy pursued at times in the past and resumed this year was to engage the technical committee chairs in assisting with session merger suggestions. The purpose of the new strategy is described in more detail in the article "Report of the Ad Hoc Committee for Fall Meeting Improvements" by Jeff McDonnell and others.

2015 Charter – AGU Hydrology Section Student Subcommittee

Tim van Emmerik (Chair), Evan Kipnis, Adam Wlostowski, Frank Sedlar, Sheila Saia, Kevin Roche, and Natasha Krell

Mission

The Hydrology Section Student Subcommittee (H3S) of the American Geophysical Union serves and represents all student members of the organization whose research interests contain a hydrological component. Committee members are dedicated to fostering dialogue between current and future generations of hydrologists, which we achieve by organizing activities at AGU meetings and online.

Organization

The committee currently comprises seven students elected by members from the previous year. Each member serves a minimum of one calendar year (Feb–Jan), up to 2 years. Meetings are held once every month and are led by the committee chair. This member is the spokesperson for the committee and has veto/tiebreaker rights over group decisions. The committee cochair is first substitute in the chair's absence, and this person also assumes leadership as chair the following year. The secretary is responsible for committee organization, meeting minutes, and email inquiries. Subcommittees are organized according to committee goals and activities, which are outlined at the beginning of the year.

Activities and Themes

The H3S successfully introduced the Student Conference and Pop-Up Sessions at the 2014 Fall Meeting. We plan to strengthen these activities in an effort to assure their sustainability, as well as to offer new opportunities in 2015. We strive to provide student members with opportunities to grow technically and socially within the broader geosciences community, an effort we have structured around the following events and themes:

- Student Conference at AGU Fall Meeting – We will offer technical activities during the 2015 Student Conference to introduce students to emergent remote sensing and field instrumentation technologies. Further information (e.g., upcoming workshop opportunities, and online resources) will be broadcast to students via social media.
- Pop-Up Sessions – Since the 2013 Fall Meeting, the Pop-Up sessions have provided a platform for early career scientists to share their vision for the future of the water sciences. Due to the success of this event, we are offering a second, special topic Pop-Up session at the 2015 Fall Meeting.
- Joint Assembly Early Career Hydrologist Night – The H3S will expand to other AGU-sponsored meetings in 2015. We will organize the first Early Career Hydrologist Night at this year's Joint Assembly meeting, which will be a full-evening program.
- Gender and Racial Equality – We are committed to fostering a safe and open environment for members of the geosciences. At this year's Fall Meeting, we will provide opportunities for all AGU members to discuss successes in and challenges to enhancing diversity. These activities will take place during both the Student Conference and a newly created Pop-Up session addressing the social dimensions of the geosciences.
- Fostering Broad Thinking – We plan to stimulate creative, forward thinking at the 2015 Fall Meeting by organizing (1) Pop-Up sessions where students present new or nontraditional research ideas and (2) a Meet the Expert session, during which students and established scientists will discuss a multidisciplinary research theme.
- Social Media and Communication with Hydrology Community – We will increase committee presence on traditional social media platforms to stimulate discussion and broaden access to available resources, which include Facebook, Twitter, and the Young Hydrologic Society website (youngHS.com). A twitter account (@AGU_H3S) will be used to increase online presence of the subcommittee. Regular interviews with early career hydrologists will be published on the AGU Water Facebook page. Lastly, the H3S is working together with Young Hydrologic Society to archive all recorded Pop-Up presentations.
- H3S Member Selection Procedure – The H3S aims to represent all AGU hydrology early career members, and all are welcome to apply for a committee position. For that reason, we will introduce a new application process for member selection. The new application will increase transparency and ensure gender, racial, and geographical equality in the selection process.

Where is Publishing in Hydrology and Water Resources Heading?

Alberto Montanari (editor in chief), Jean Bahr, Günter Blöschl, Ximing Cai, D. Scott Mackay, Anna Michalak, Harihar Rajaram (editors)

As a top-quality scientific journal, *Water Resources Research* (*WRR*) provides a timely perspective on the most interesting research challenges addressed by the international hydrologic community. The editors of the journal have the opportunity to get a comprehensive picture of the published contributions and the related review reports. For this reason, students and colleagues frequently seek the advice of the editors, to get our opinion on the promise/potential of a research idea and the most exciting research questions. Researchers tend to be drawn toward exciting and novel research trends, which are often inspired by new international scientific initiatives, novel observations enabled by emerging technologies, and urgent real-world problems. Therefore, a young researcher should certainly follow and critically evaluate contemporary research trends. *WRR*, in view of its international prestige, certainly offers an interesting panorama.

To provide an objective summary of the main topics addressed by published *WRR* papers, one may look at the related index terms. The AGU index terms (see http://publications.agu.org/author-resource-center/author-guide/index-terms/) identify the subject of each published contribution. Any paper may refer to three to five index terms. Figure 1 displays the occurrences of the main index term categories in the published *WRR* contributions in 2013 and 2014.

Apart from the dominating role of the index term "Hydrology," which, of course, appears in almost all papers, it is interesting to note that the second most used term is "Natural hazards," followed by "Informatics." The significant role played by "Biogeosciences" highlights the emerging role of that area. "Global change" and "Atmospheric processes" display comparable relevance, as well as "Mathematical geophysics." "Oceanography" and "Cryosphere" are also important, and it is interesting to note the relevant role played by "Policy sciences," therefore highlighting another emerging field.

A classification compiled by the editors for the papers published in 2013 pointed out that about 30% of these contributions deal with groundwater and soil science, while about 15% refer to river processes (river hydraulics, river temperature, sediment transport, river morphology, etc.). Ecohydrology, floods, and droughts cover about 5% of the papers each, while water quality, climate processes, uncertainty, hyporheic exchange, and water policy count for about 2% of the contributions each.

The above distribution of subjects is, of course, not comparable with the picture of 30 years ago, when system theory and applied water resources management were dominating the interest of researchers. What is surprising, in comparison with the past trends, is the striking dominance of modeling studies and the index term "Informatics." In fact, the massive increase of computing power that occurred since the 1990s radically changed the research activity in water resources.

Comparing the past and present publications, another relevant difference immediately emerges, namely, the globalization of hydrology, facilitated by the Internet and other technologies that allow communication and collaboration. International cooperation has risen significantly, and, as a result, the number of authors per paper has increased as well [*Montanari*, 2014].

Predicting the future is a challenge, but the publication market and research trends will definitely change much faster than in the past. In view of the above globalization, international connections and data sharing are increasing dramatically, therefore offering exciting perspectives for global and interdisciplinary studies. In fact, interdisciplinarity is emerging as one of the keys to gaining a better understanding and interpretation of the water cycle, by using interrelated processes to study interactions and feedbacks. Interdisciplinary modeling is not straightforward; one needs to identify the relevant processes and represent their connections while keeping the model flexible and parsimonious. However, there is no doubt that chemical, biological, ecological, and societal dynamics are impacting water resources management more and more, and therefore need to be accurately and efficiently modeled. In particular, the impact of societal evolution on the water cycle is dramatically increasing and calls for an improved representation of the related feedbacks. Moreover, global hydrology will become increasingly important, in order to study water problems across the boundaries of single catchments and countries.

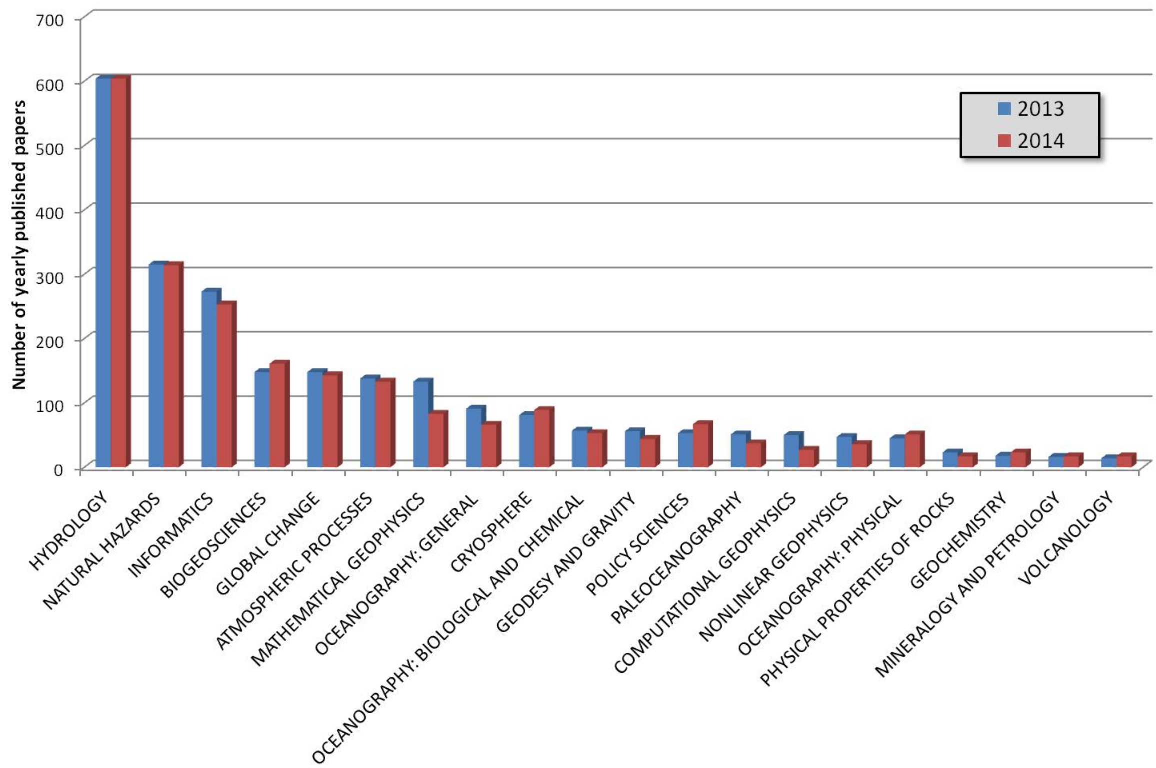

Figure 1. Number of yearly published papers in *WRR* in 2013 and 2014 for selected index term categories.

As we look forward, from our privileged perspective, we expect that new measurement techniques and new data processing will be primary subjects of research in the near future. We see the increasing need to support hydrological studies with more refined knowledge, and enhanced theories, allowing us to profit from the new generation of spatially distributed and remotely sensed information. There will be a need to bridge the scale gap between local problems and the global challenges they are inducing. Water resources are frequently managed at the local scale of a single catchment or water resource system, but solutions need to be devised with a global vision, to take into account water transfers that are occurring at increasing spatial scales (e.g., through virtual water trade). A global vision will be key to anticipating the challenges and scientific trends for water resources management in the 21st century.

Furthermore, we foresee that research in the future will need to bridge the gap between hydrology and engineering. Environmental change is dictating the need for adapting water infrastructures to changing boundary conditions and internal dynamics. While hydrology has made relevant progress in deciphering the impact of environmental change, engineering design still relies heavily on the passive use of modeling approaches that were devised several decades ago, often without accounting for uncertainty. There is a need to integrate deterministic and stochastic models into a unified framework to take advantage of improved process understanding and uncertainty assessment methods. Moreover, multiobjective planning for water quantity, water quality, and environmental quality offers the exciting opportunity to take advantage of interdisciplinary modeling to address water resources, environmental quality, and ecosystem sustainability.

The above challenges should be pursued on the basis of a profound knowledge of the literature. The increasing number of scientific contributions makes even more compelling the need to support scientific research with a solid assessment of previous studies.

To conclude, we see an exciting future for hydrology, with a lot of room for creativity. The main ingredient of our suggested recipe is a strong motivation to look ahead, and a strong curiosity to follow the literature and to anticipate the opportunities offered by new measurement techniques. There are several papers recently published by *WRR* that provide exciting inspiration. Please contact us at wrr@agu.org if you would like to get our opinion on specific issues. We look forward to providing our best advice.

Finally, let us conclude this piece with a personal note: after 6 years of service as *WRR* editor, Graham Sander decided to step down from 1 May 2015. He was replaced by Xavier Sanchez-Vila (Universitat Politècnica de Catalunya), who has an outstanding record of contributions to *WRR* as associate editor. We are pleased to welcome Xavier on board. We are sure his contributions as editor will be appreciated by *WRR* authors. We would like to take this opportunity to express our deepest gratitude to Graham. His service to *WRR* has been excellent. We will never forget Graham's dedication and professional approach, as well as his supportive attitude. Thanks a lot, Graham!

Atmospherically Accessible Water

W. James Shuttleworth - 2014 Robert E. Horton Medalist
Dept. of Hydrology and Atmospheric Sciences, University of Arizona

Here we consider the distinction between hydrological and meteorological perspectives on "soil moisture," discuss the true nature of "atmospherically accessible water" present near land surfaces comprising soil and vegetation, and, on this basis, mention some of the challenges associated with new technologies that seek to sense the water present near the soil-vegetation-atmosphere interface from above-surface observations.

Soil moisture means different things in different disciplines. To the hydrologist, soil moisture is the water that is held in the spaces between soil particles in the vadose zone. To the meteorologist, soil moisture is a model-derived state variable that controls the instantaneous return of water vapor to the atmosphere, determined by making a running water balance between inputs and outputs to a surface water store, which, for conceptual simplicity, is envisioned as a finite depth of porous soil. Because this conceptual entity is so important in predictive meteorological modeling, there has been investment in new technologies that seek to quantify it as an area-average value from above-surface observations that depend on the physical properties of water. Two important examples of such observations are microwave remote sensing satellites such as SMOS [e.g., *Kerr et al.*, 2010] and SMAP [e.g., *Entekhabi et al.*, 2010] and cosmic ray sensors such as those used in the COSMOS project [e.g., *Zreda et al.*, 2012]. But what is the true nature of the near-surface water stores at the soil-vegetation-atmosphere interface and what challenges are involved in seeking to use such above-surface observations to try to quantify these stores?

Figure 1 shows the water stores present in vegetation-covered soil that are accessible to the atmosphere, along with the typical timescales involved in atmospheric exchange with these stores. In order of magnitude terms, the water stores with shorter timescale interactions are typically a few millimeters, while those with longer timescales inside vegetation and soil are typically an order of magnitude or more greater.

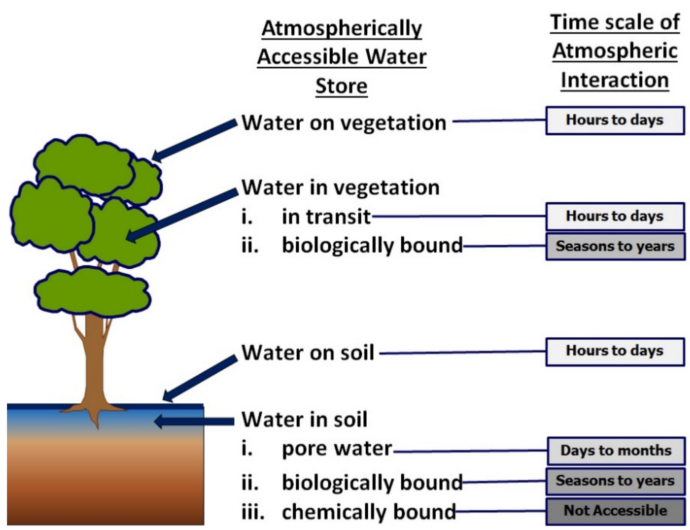

Figure 1. The near-surface stores of atmospherically accessible water and the typical time scale of their interaction with the atmosphere.

The key point here is that above-surface observing systems sense all of the water in these several differently atmospherically accessible stores to some extent, and they respond with greatest efficiency to water stored higher in the system and closer to the atmosphere. For example, in the simple case of pore water stored in bare soil, microwave remote sensing systems observations will preferentially sense water only in the top few centimeters, while cosmic ray observations preferentially sense the water in the top 10 centimeters or so.

One feature clearly apparent in Figure 1 is that not only pore water but also biological water in both aboveground and belowground vegetation is atmospherically accessible, albeit with longer interaction timescales. To illustrate this, Figure 2 (redrawn from *Franz et al.* [2013]) shows the seasonal changes in near-surface biological water storage sensed for a maize crop growing in moist soil where the pore water store was independently measured using multiple gravimetric samples and was in the range 60–90 mm.

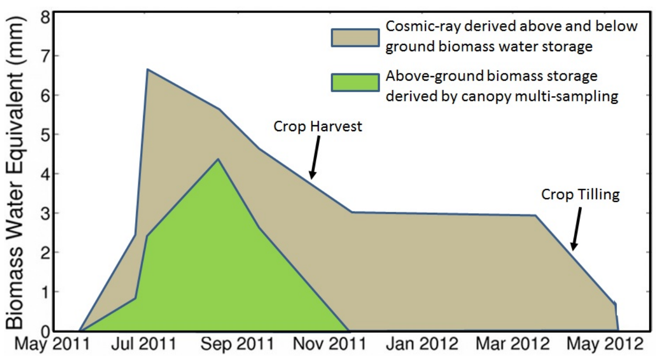

Figure 2. Seasonal evolution of atmospherically accessible water in near-surface biological water stores for a maize crop growing in moist soil [see *Franz et al.*, 2013]. Note that errors in the cosmic ray–derived aboveground and belowground biomass water storage are of the order 1 mm.

The green shaded area is the seasonal variation in aboveground biological water measured by taking multiple manual samples of the crop, while the brown shaded area shows the seasonal variation in water equivalent of both aboveground and belowground biomass as measured by a cosmic ray sensor. The aboveground biological water storage falls during fruit development/ripening in August and September and is then removed by harvesting by November, but the belowground biological water storage remains until tillage occurs in the following May. Thus the water stored biologically in this particular crop varies with season and has an order of magnitude of 10 mm. *Franz et al.* [2013] also report that the biomass store for a stand of forest vegetation was around 25 mm, with less seasonal variation. The point is that biologically stored atmospherically accessible water is not necessarily negligible, and it can have a different time dependency than that stored as pore water in the soil. Arguably, this suggests that if the full benefit of assimilating above-surface sensor observations of near-surface water storage is to be obtained, the land surface model into which these data are assimilated should include representation of dynamic aboveground and belowground biological water storage.

Recognizing the true nature of atmospherically accessible water as in Figure 1 also has a second consequence for the land surface model used for assimilation. A portion of the water sensed belowground is neither pore water nor biological water: It is water that is chemically bound to the soil lattice that is only released when the soil is raised to high temperature. This water storage is not therefore atmospherically accessible, and the presence of this nonaccessible water still sensed by above-surface observing systems should be recognized during data assimilation. Quantification of the amount of this "lattice water" carried out in the COSMOS project at many sites across the continental United States indicates site to site variability and that lattice water can be as much as 7% of the water stored belowground in accessible form as pore water, and a much greater proportion than this in the volcanic soils of Hawaii.

Because the conceptual "soil moisture" calculated by land surface models within meteorological models or Land Data Assimilation Schemes (LDAS) is a model-derived entity, its validity depends on the realism of the land surface model used and the accuracy of the weather variables used in the calculation. Arguably, for some land surface models, especially those used in weather forecasts, the parameterization of how changes in the conceptual soil moisture alter evapotranspiration has been subtly "tuned" to improve the description of surface energy exchanges and thence model-calculated near-surface atmospheric variables. However, this does not mean that the absolute value of the modeled soil moisture necessarily reflects the true area-average soil moisture, an issue that will presumably become more visible as models and LDAS move toward "hyperresolution" and the complications of making grid scale comparisons become less severe.

The emerging capability to measure actual area-average soil moisture from above-surface observations has highlighted the discrepancies that can occur. R. Rosolem (private communication, 2015), for example, compared site-average soil moisture observed using a cosmic ray probe with soil moisture calculated with the Noah model forced by observed near-surface weather variables at two semiarid sites. There were substantial systematic differences, and assimilating the actually observed soil moisture into the Noah model destroyed its ability to calculate realistic surface energy exchange, although it was possible to obtain some improvement by calibrating the soil parameters in the Noah model against the observations of soil moisture and surface fluxes. Similarly, *Caldwell et al.* [2013] compared calculated soil moisture given by the NLDAS system with above-surface cosmic ray observations and other in situ observing systems at many sites and reported significant differences between NLDAS and observations that varied significantly with location. It is therefore important that hydrologists and agricultural scientists are fully aware that the soil moisture model-calculated data that can now routinely be provided by meteorological models and LDAS ought not to be used in hydrological or agricultural applications without validation and/or recalibration.

Even though the data products provided by satellite systems do not currently recognize the diversity of atmospherically accessible stores sensed by above-surface observations, it is likely that the rate of change in the measure of near-surface water storage that they provide and call "soil moisture" will have the potential to provide improvement in the model-calculated fields of surface exchanges when assimilated into meteorological models or LDAS with equivalent complexity. But should the "soil moisture" products also be directly used in hydrology and agricultural applications? Even if the surface were bare soil, the fact that the basic observation is only of the top few centimeters of soil means that the remainder of the soil moisture profile provided in any secondary model-derived remote sensing product is again dependent on the realism of the land surface model and accuracy of the weather variables use in the calculation. To give emphasis to this point, Figure 3 illustrates how (in the parlance of a portion of the hydrological community) there can be "equifinality" in the profiles of soil moisture that are consistent with a near-surface measurement of soil moisture in a shallow surface layer. Hydrologists and agricultural scientists should therefore also be wary about applying model-calculated secondary remote sensing products without validation and/or recalibration, and realize that such recalibration might only be locally applicable.

In summary, here we seek to highlight two main points: (1) Atmospherically accessible water near land surfaces comprising soil and vegetation exists in several distinct stores, and data from above-surface observing systems should optimally be assimilated using land surface

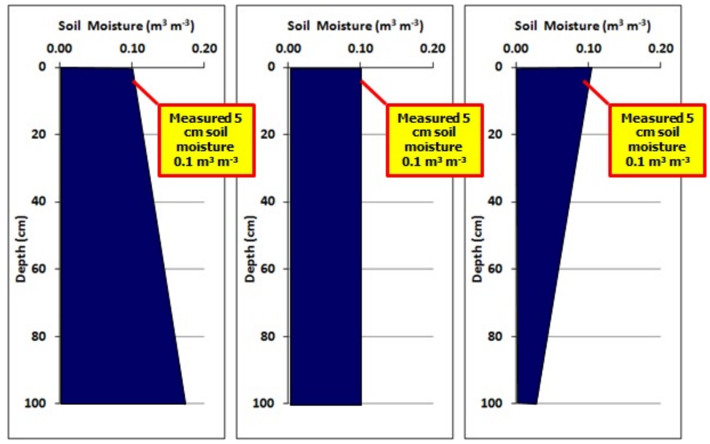

Figure 3. Illustrating "equifinality" in model-calculated soil moisture profiles, i.e. that there is a wide range of model-calculated profiles consistent with (say) a measured 5-cm-deep observation of soil moisture.

models that recognize these distinct stores; and (2) the conceptual soil moisture represented in meteorological models, LDAS, and secondary remote sensing products is a model-derived entity whose credibility is dependent on the realism of the land surface model and accuracy of the weather variables use in their calculation; they should only be used in hydrological and agricultural (as opposed to perhaps meteorological) applications after validation and/or recalibration. The bottom line is, "Just because one chooses to call it soil moisture doesn't mean it is soil moisture."

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Note: A link to the Horton Medal acceptance speech is available at: http://www.hwr.arizona.edu/~shuttle/Shuttleworth_Horton_2014.mov

Trait-Based Ecohydrological Modeling: Reevaluating Long-Standing Questions

Stefano Manzoni - 2014 Hydrologic Sciences Early Career Awardee
Department of Physical Geography and Bolin Centre for Climate Research, Stockholm University, Sweden

I am honored to receive the 2014 Hydrologic Sciences Early Career Award, and I am grateful to the colleagues who nominated me for this award. Most important, I would like to thank numerous colleagues and collaborators I had the opportunity to work with. My research activities at the intersection of hydrology, ecology, and biogeochemistry would not be possible without the interdisciplinary team effort I was lucky to be part of.

As we all realize from personal experience, plant species can be markedly different. Not only their morphology varies, but also their functional traits that mediate how species respond to environmental factors and acclimate to altered climatic conditions. Soil microorganisms are harder to "see" than plants, but they also exhibit a staggering diversity in functional trait values, encoding a wide range of adaptation strategies [*Lennon et al*., 2012]. Each set of traits determines the performance of plants and microbes in their environment and in relation to other organisms. Because selective pressures favor organisms with functional traits that provide a fitness advantage, optimality principles can be exploited to identify the most successful trait values—and thus the model parameters that encode such traits. An optimality principle basically constraints the parameter space in hydrologic and biogeochemical models by selecting parameter values that are most likely from an ecological point of view. Much of the recent research activities we carried out at Duke University, and later at the Swedish University of Agricultural Sciences and Stockholm University, aim at developing models where uncertain or unknown processes and parameters are surrogated by suitable optimality conditions.

Plant activity interacts with water availability: Soil moisture fuels transpiration and thus photosynthesis, but transpiration depletes soil water, thereby inducing plant water stress in the absence of rainfall. Exploiting water resources or saving water to avoid stress represents an evolutionary dilemma that plants face by balancing water losses and savings through stomatal control.

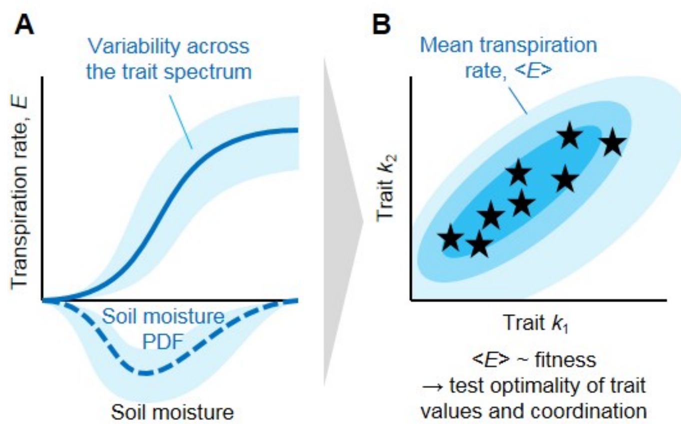

Figure 1. Illustration of the linkages between plant functional traits and hydrologic processes. (A) Plant traits affect water transport from the soil to the leaves and evaporation through stomata, thus altering the shape of the transpiration-soil moisture relation (shaded area around the solid line). Transpiration rate in turn affects the soil moisture balance, thereby shifting the soil moisture probability density function (PDF; shaded area around the dashed line). (B) As a result of trait variation, the long-term mean transpiration rate, <*E*> (a proxy of plant fitness) varies across the trait spectrum (contours indicate <*E*>; stars denote observed trait values). Some trait values and combinations ensure optimal water use in a given climate, as indicated by darker shades [*Manzoni et al*., 2014c].

It has been hypothesized that stomatal movements are optimal; i.e., they maximize CO_2 uptake while avoiding unnecessary depletion of soil moisture [*Cowan*, 1986]. This optimality principle does not explain all the signaling mechanisms responsible for stomatal movement. However, it assumes that the collective behavior of all the signaling mechanisms responsible for stomatal movement operate to achieve a goal—to maximize carbon gain for a given soil water availability state. This goal (technically, the Hamiltonian of the optimization problem) provides closed-form relations between transpiration rate and soil moisture during dry periods that can be employed in ecohydrological models instead of empirical relations [*Manzoni et al*., 2013]. A similar concept can be employed to explain correlations among functional traits as emerging optimal patterns. Following this approach, we showed that stomatal closure is coordinated to the loss of xylem conductivity during drought in such a way as to maximize the long-term mean water use (Figure 1) [*Manzoni et al*., 2014c]. Coordination among traits also prevents catastrophic hydraulic failure during intense droughts because it allows avoiding hydraulic bottlenecks upstream of the stomata [*Manzoni et al*., 2014a].

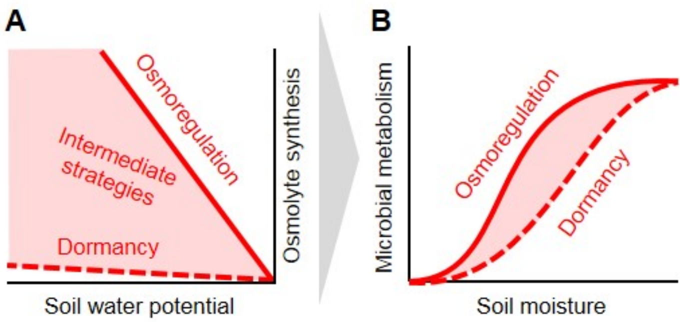

Figure 2. Illustration of the linkages between microbial functional traits and biogeochemical processes, considering osmoregulation as an example. (A) Microbes can adopt different strategies to cope with limited water, ranging from active osmoregulation that ensures stable turgor (solid line), to drought avoidance through dormancy (dashed line). (B) Microbial strategies generate a range of responses of microbial metabolic rate (e.g., respiration) to soil moisture. In turn, these response functions are employed in biogeochemical models to parameterize the role of moisture on reaction rates (see details in *Manzoni et al*. [2014b]).

Microbes also face water-related dilemmas. By synthesizing osmolytes and extracellular polysaccharides, soil microbes can withstand negative water potential levels as soils dry [*Schimel et al*., 2007]. However, producing these compounds requires substrates and energy, which become less and less available during drying due to reduced solute diffusivity and hydraulic connectivity in the soil pores. As an alternative to produce "expensive" compounds to resist water stress, microbes can also become dormant and avoid water stress conditions (Figure 2). Because dormant microbes might miss opportunities for substrate uptake, early transition to dormancy is not advantageous—especially if the dry periods are typically short [*Manzoni et al*., 2014b]. Which functional traits define optimal strategies in a given environment remains unclear, but microbial communities subjected to drought treatments are more tolerant to hydrologic fluctuations, suggesting that optimal adaptations might indeed occur [*Evans and Wallenstein*, 2013].

Despite this variability in functional traits, some ecosystem-level properties are remarkably stable. For example, the rate of transpiration from forests has been shown to be often conserved [*Roberts*, 1983]. Similarly, the soil moisture level at which microbial communities stop being active due to lack of water tends to be stable across soil types and ecosystems [*Manzoni and Katul*, 2014]. This apparent contradiction between physiological and system-level evidence begs the question of whether and when we can detect the signatures of physiological traits in broad-scale hydrologic and biogeochemical patterns. In other words, are species-specific adaptation strategies significant over large scales? This is not a new question in hydrology [*Jarvis and McNaughton*, 1986], whereas it has only recently been considered in biogeochemical modeling. Microbial processes and traits are now being explicitly included in biogeochemical reaction models and are opening new vistas to model developments [*Todd-Brown et al*., 2012]. Different from the hydrologic sciences where theories have been developed to cross scales from plant tissues or soil pores to stands and catchments, soil biogeochemical models still lack much of the cross-scale information flow that would make ecosystem-level models physically sound. Developing this cross-scale communication represents an exciting area of research, which might benefit from existing theories, such as percolation theory [*Hunt and Ewing*, 2003]. For example, using this approach, *Manzoni and Katul* [2014] showed that the invariance of the moisture threshold for microbial activity in dry soils can be explained as the moisture value where pore hydraulic connectivity breaks down.

In closing, by bridging several disciplines within the natural sciences and utilizing approaches successful to economics (e.g., carbon-water economics and optimization) and physics and material science (e.g., percolation theory) the full spectrum of biological feedbacks on hydrological processes can be accounted for. As shown in the past, it is likely that, in some cases, large-scale hydrologic and biogeochemical processes are dictated by abiotic properties and climatic drivers, rather than plant and microbial physiology. However, when and where this decoupling between the abiotic and biotic worlds actually occurs is an exciting problem for the future.

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A Fellow Speaks: Opportunities and Fortunes in Global Hydrology

Taikan Oki
The University of Tokyo

Even though I have been a member of AGU for more than two decades, I paid no attention to the honor of becoming an AGU Fellow because I thought it was none of my business. After I was notified that I was elected a Fellow, I was both humbled and honored to realize the prestige this recognition carries and to know that I am the first Japanese AGU Fellow in the Hydrology Section. I would like to extend my sincere gratitude to the colleagues who spent special efforts to nominate me.

In 1987, when I entered the Graduate School at The University of Tokyo, I came across the article of *Bras et al.* [1987], which termed Hydrology in the late 20th century as "The forgotten Earth science." At that time, hydrological sciences supported human well-being by reducing risks associated with extremes (scarcities and excess of water) through management. However, the work was largely isolated from other tightly coupled Earth sciences, such as meteorology, oceanography, and geology. As *Bras et al.* [1987] pointed out, there was an impending need to build a more coherent understanding of the global water cycle in its full complexity.

As a master's student, I chose to work on research related to orographic rainfall, because I thought rainfall is the major driver of floods and droughts and fundamental to the advancement of hydrology. I tried to develop a simple atmospheric model, which could relate upwind areas with orographic rainfall distribution estimated from rain gauge network data. I was very lucky that I had the opportunity to present the results of my master's thesis in the Pacific International Seminar on Water Resources Systems in Tomamu, Hokkaido, Japan, in summer in 1989. Prof. Soroosh Sorooshian coorganized the meeting, and strongly encouraged me to submit the results I presented to *WRR*, of which he was the editor at that time. I knew nothing about submitting a journal paper, but Soroosh helped me a lot, and finally I could publish my result as an article in *WRR* [*Oki et al.*, 1991].

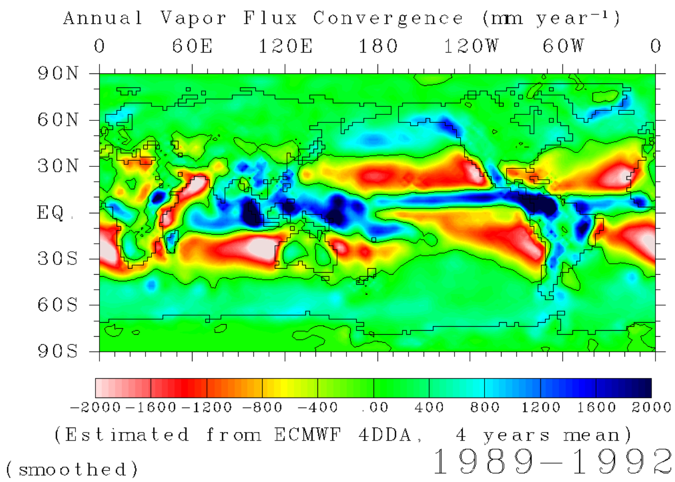

Figure 1. Vertically integrated annual water vapor convergence (mm year^{-1}) mean from 1989 to 1992, updated from *Oki et al.* [1995]. Positive value corresponds to annual excess of precipitation over evapotranspiration. Slight negative values over land are mostly due to the limitation of the accuracy of the methodology and data, but partially regarded as the impacts of irrigation, with which evapotranspiration from cropland can be larger than local precipitation.

Being a member of the research group of Prof. Katumi Musiake at IIS/UT, whose research was dedicated to urban hydrology, I felt at that time isolated in pursuing my interests in atmospheric modeling. However, I had an opportunity to study physical climatology from Dr. Kooiti Mauda using a text by Prof. Oort (published later as a book [*Peixöto and Oort*, 1992]). I was extremely fascinated with the concept of atmospheric water balance [e.g., *Peixöto*, 1970; *Peixöto and Oort*, 1983] and eager to update the estimates.

Fortunately, the 1980s were the dawn of four-dimensional data assimilation (4DDA) of global atmosphere. I was really excited to calculate the vertically integrated water vapor convergence (Figure 1) utilizing operational analyses by ECMWF and JMA, even though I had to handle several dozen magnetic tapes at the computer center. Another fortune was that Prof. Murugesu Sivapalan participated in IAHS in Yokohama, Japan, in 1993; he also gave a seminar at IIS/UT, and he found my research on atmospheric water balance interesting. He invited me to a workshop in Robertson in 1994, and I could publish the results [*Oki et al.,* 1995] in the special issue of *Hydrological Processes*, for which Siva was the guest editor. I'll never forget how enthusiastically Siva helped me revise and improve the paper. I believe *Oki et al.* [1995] was one of the first papers to demonstrate the potential capability of 4DDA data to estimate terrestrial water balances through the combined use of global precipitation observations and large basin river discharge based on the atmospheric water balance (AWB) method. *Oki et al.* [1995] opened the door to global water balance studies by AWB in the modern era. Our approach, using 4DDA data, is now commonly applied to estimate global water balances, even though reanalysis data, the postprocessed version of 4DDA data, is more popular than operational analysis data.

Afterward, I had an opportunity to spend 2 years at NASA/GSFC as a visiting scientist, and had some free time to work on time-consuming research such as manual correction of a global river channel network, named "TRIP" [*Oki and Sud*, 1998]. I was also fortunate to have an opportunity to participate to the 2nd phase of the global soil wetness project (GSWP2), and validated the accuracy of the global water balance estimated by 11 land surface models (LSMs), that are a part of GCMs and provide lower boundary conditions to the atmosphere, with a simple river routing scheme [*Oki et al.*, 1999]. TRIP and the river routing scheme were widely adopted by several GCMs in the world, for example, six out of 23 future projections employed in the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) utilized TRIP. Even now, TRIP is coupled within a latest Earth System Model and a GCM. In summary, *Oki and Sud* [1998] filled a missing link in the water cycle of GCMs and expanded their utility into river flood events.

I'm quite happy to see that *Oki et al.* [1999] established a framework for evaluating global water cycles via off-line (uncoupled with atmosphere) simulation of LSMs combined with river routing schemes. At present, the framework is commonly used to assess LSM accuracy and improve them by thorough validation, and calibration to observed river discharge. The framework is also useful for translating climate change–driven changes to hydrological cycles (projected by GCMs) into socially relevant information, such as changes in the frequency of floods and droughts [e.g., *Nohara et al.*, 2006; *Hirabayashi et al.*, 2008]. The 2nd phase of the Global Soil Wetness Project (GSWP2) also utilized this framework [*Dirmeyer et al.*, 2006], and a comprehensive review of the global hydrologic cycle and world water resources based on the estimates from GSWP2 were published in Science [*Oki and Kanae*, 2006]. Establishing a scientific illustration of the global hydrological cycle (Figure 2) has been one of my

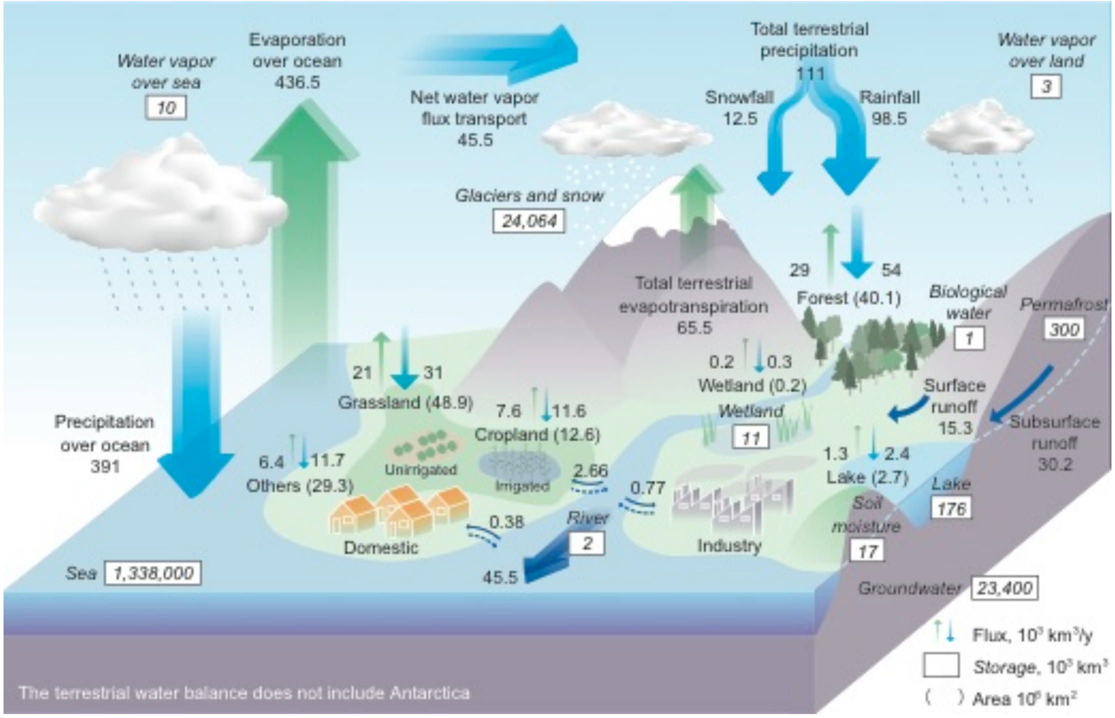

Figure 2. Global hydrological fluxes (1000 km^3 yr^{-1}) and storages (1000 km^3) with natural and anthropogenic cycles are synthesized from various sources. Big vertical arrows show total annual precipitation and evapotranspiration over land and ocean (1000 km^3 yr^{-1}), which include annual precipitation and evapotranspiration in major landscapes (1000 km^3 yr^{-1}) presented by small vertical arrows; parentheses indicate area (million km^2). The direct groundwater discharge, which is estimated to be about 10% of the total river discharge globally, is included in river discharge. The values of area sizes for cropland and others are corrected from original ones. From *Oki and Kanae* [2006].

dreams and goals, and I felt really accomplished with the publication.

However, real hydrological cycles are often influenced by anthropogenic activities, such as reservoir operations and water withdrawals for human needs, and differ substantially from natural hydrological cycles. Even though human withdrawals are indicated, Figure 2 critically lacks the artificial reservoirs. The first integrated water balance and water resources model considering major human interventions on a global scale was developed by *Hanasaki et al*. [2008], named as H08. H08 is coupled with submodels of reservoir operation, human water withdrawal, environmental flow, and crop growth, in addition to a natural water balance sub-model. Recently, the human intervention components were transplanted into an LSM, which was then applied to assess the impacts of changes in the terrestrial water storage on trends in the global mean sea level [*Pokhrel et al*., 2012].

The field of global hydrology today has certainly evolved and established itself nearly 3 decades after *Bras et al.* [1987] led the call for greater prominence. Current hydrology has a capability to monitor, understand, and predict global hydrological cycles of social-ecological systems, combining both human and natural systems. I am gratified to see that global hydrology has a prominent place among other Earth sciences now. I cannot list the names of all my colleagues who contributed to the development of the field, either as a student, as a postdoctoral fellow, or as a collaborator, but I appreciate very much their untiring dedication and significant contributions. I feel I have been just lucky in my research life, but I'm very proud to have witnessed the evolution of global hydrology as one of Earth system sciences.

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A Fellow Speaks: A "TOGA COARE" Program for Continental Hydrology and Hydrometeorology

Ana P. Barros
Duke University

It's been roughly 25 years of unexpected privilege since my early days as a graduate student at the University of Washington, for which I am deeply grateful. Born in Angola in the headwaters of the Congo River Basin, one of my earliest memories is that of watching Neil Armstrong step on the moon in 1969, a grainy movie on an odd screen, a momentous event played again and again on an improbable shop window in downtown Luanda on the day of my birthday. Twenty-something years later, NASA's EOS (Earth Observing System) program was in many ways the "stepping on the moon" for Earth Sciences. For us in Hydrology and Hydrometeorology, it was a "watershed" moment, with the global planet as study domain and unprecedented observations available over unprecedented ranges of spatial and temporal scales.

EOS observations of the Dynamic Earth and the increasing data analysis, synthesis, and modeling capacity afforded by High-Performance Computing prompted new research directions and the development of interdisciplinary "many – a – hyphen" science (hydro-eco-geo-met-…..) and scientists. Global observations highlighted the importance of climate and orography in the organization of the Earth's water transfers and moisture transport from remote to local scales. New satellite observations brought the Water Cycle to the forefront of Earth Sciences.

From seasonal albedo changes of 30% at spatial scales of 10s to 100s of km^2, to the diurnal cycle of subdaily precipitation variability and soil water storage, water and energy budget closures are within reach at mesoscales. We find that, in the context of the coupled land-atmosphere system, it is the spatial range of water cycle teleconnections that determines the effective boundaries of the River Basin including an airshed that spans the regional moisture source regions, and a landshed that partitions rainfall, distributes groundwater between basins below mountain ranges, and delivers runoff to the canonical terrestrial outlet. Upstream and downstream are space-time varying concepts: earlier studies showed that cutting trees in the Amazon changed rainfall there and downwind in the Andes; recent studies show that cutting trees in the Andes changes the rainfall there and over the Amazon Basin. "Everybody lives downstream" as the world becomes smaller because we can model and measure more and better at increasingly higher resolution; on the ground, it becomes ever more important to travel far with the aid of new technology to discover processes governing phenomena we are only now beginning to "see," and then measure them, and develop and/or refine and test hypotheses new and old. "Occult" precipitation is no more, as ground-based microphysical measurements from the micron to millimeter scale are now routinely possible; we now know fog and low-level clouds in the Appalachians can account for as much 50% of the annual freshwater input. These findings have changed our perspective on rainfall-runoff response, on the time scales governing surface-subsurface interactions, on the proactive role of ecosystems in weather and climate, and on our understanding at the boundaries among chemistry, ecology, and physics.

Focusing on complex system behavior using models and parameterizations without elucidating upscale causation laws linking fundamental processes to emergent behavior has not yielded the transformative advances in understanding we have endeavored for. As we navigate through large volumes of remote sensing data and vast repositories of model results with apparent ease and efficiency, the predictability of emergent behavior (e.g., drought onset and drought recovery among others) remains no less a challenge today than it was decades ago. Truly integrated ground-based observing systems and experiments guided by first principles are needed to develop, evaluate and test Earth Systems Models, which are the (virtual) laboratories where complex systems can be comprehensively studied. To move away from correlation to understanding, multiscale, collocated, concurrent measurements of the water cycle within and across the land-atmosphere interface are required. Yet, broadly agreed upon baseline metrics standards for field observations are lacking. Catchment-based coupled water and energy balance closure over a range of scales are desired metrics. In the same way that the "TOGA COARE" (Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Response Experiment) program was instrumental in advancing the understanding of ocean-atmosphere coupling, the time seems right to call for a "TOGA COARE"-like comprehensive program to elucidate local and remote coupled hydro-bio-geo-chemical-physical processes, including the role of large mountain systems in organizing both atmospheric moisture and subsurface transport and storage over short and long timescales. There is a rich infrastructure of observational systems and networks in North America that can be leveraged, and then augmented for this purpose. A Community Science Plan that spells out critical science questions, defines an ambitious and inclusive research strategy, and boldly establishes a plan for achieving scientific milestones for the next decade is within reach. Through the leadership of the Hydrologic Sciences and Physical Meteorology programs at NSF, a workshop in 2014 provided a first opportunity for the community to begin a conversation about these issues. It is incumbent upon us colleagues to build on existing momentum. I trust many among us share this vision.

Let us work together.

Soil Moisture Active Passive (SMAP): New Remotely Sensed Hydrological Data and Opportunities

Alexandra Konings[1] and Erika Podest[2]
[1]Massachusetts Institute of Technology, [2]NASA Jet Propulsion Laboratory

Climate- and weather-related hazards such as the ongoing drought in California and record snowfall in the Northeast have greatly increased the relevance of hydrologic science to public discourse. Any response to such events rests on our ability to detect and monitor these phenomena, which is a direct result of international investments in satellite remote sensing platforms specifically designed to observe the global hydrologic cycle. Existing satellites measure several components of the global water cycle, including precipitation, snow cover, total water storage, open water bodies and inundated vegetation, among others. The most recent hydrologically focused NASA satellite is the Soil Moisture Active Passive (SMAP) satellite, which was launched on 31 January 2015 [*Entekhabi et al.*, 2010].

SMAP is producing global soil moisture maps (representing up to the top 5 cm of the soil) every three days at 9 km resolution. The time of overpass at the equator is at a constant local time of 6:00 am, before the onset of evaporative stress. Since soil moisture lies at the heart of the coupling between the water, energy, and carbon cycles, this data holds great promise for enabling improvements in both basic sciences and operational weather and climate predictions. SMAP surface soil moisture data is also being assimilated into global land surface models to provide continuous estimates of 'root-zone' soil moisture (top 1 m) and net ecosystem exchange (NEE). Lastly, SMAP is also producing maps of the frozen/thawed state of the land surface in boreal regions, a major predictor of soil carbon fluxes. All SMAP data will be freely available online through the National Snow and Ice Data Center (https://nsidc.org/data/smap) and the Alaska Satellite Facility (https://www.asf.alaska.edu/smap/).

SMAP has two instruments, a radar and a radiometer, both operating in the L-band frequency range of the electromagnetic spectrum. This allows SMAP to sense the surface of the Earth regardless of cloud cover. This frequency range is also very sensitive to soil moisture and to the frozen or thawed state of the land surface. In 2009, ESA launched the Soil Moisture Ocean Salinity or SMOS satellite [*Kerr et al.*, 2010], which carried a radiometer only and had a relatively coarse resolution of ~43 km. SMOS also had unexpected struggles with radio frequency interference (rogue transmitters) that SMAP has learned from. SMAP will combine radiometer data (which allows for accurate estimation of soil moisture but at relatively coarse resolution -36 km), with radar data (which allows for estimation of soil moisture at a much higher resolution—3 km—but with lower accuracy) to generate SMAP's flagship product—soil moisture at 9 kilometer resolution with an accuracy of less than 0.04 cm^3/cm^3. The capability to provide global soil moisture measurements every 3 days at 9 km resolution makes this mission unprecedented. The radar data will also be used to produce binary maps of the frozen or thawed state of the land surface for areas 45 degrees north latitude at a resolution of 3 kilometers and a temporal sampling of 2–3 days.

The freeze/thaw product will quantify the nature, extent, timing, and duration of landscape seasonal freeze/thaw transitions and will contribute to understanding how boreal ecosystems respond to and affect global environmental change. When the land surface thaws across boreal forests, vegetation becomes productive and acts as a carbon sink. Identifying the timing of the spring transition from frozen to thawed is important because it marks the beginning of the vegetation growing season across regions that freeze during the winter. Similarly, with the onset of the winter freeze, carbon dioxide uptake shuts down. Depending on the length of the vegetation growing season, a boreal forest stand can be either a net carbon source or carbon sink in the global carbon budget. The timing and variability in freeze/thaw also influences the hydrology of the land surface because water from melting snow infiltrates into thawed soil but not into frozen soil.

The soil moisture data made by SMAP have a variety of benefits for operational applications. Improved initialization and assimilation of soil moisture data can significantly increase the predictive skill of numerical weather prediction models and climate forecasts. Soil moisture data are also useful for drought monitoring and predicting potential natural hazards such as (flash) floods and wildfires. Soil moisture observations are also useful for monitoring and predicting agricultural productivity. Also, since many disease vectors are affected by the availability of water, SMAP data are also useful for a variety of human health applications.

Aside from the many direct societal applications of SMAP data, the new observations can also be of great value for basic science studies. Because of the high spatial variability of soil moisture, in situ measurements require dense sampling to be representative of larger areas (cosmic ray neutron probes may overcome this problem, but they are not yet cheaply available or easily calibrated). In addition, in situ soil moisture is lacking over much of the globe. In these areas as well as in many remote locations, data from SMAP can be invaluable for understanding soil moisture dynamics.

Because soil moisture affects and is affected by several other hydrological and ecological variables, data from SMAP will lend itself well to synergistic studies with data from other current and future Earth observing satellites, including GPM, GRACE, OCO-2, and others. For example, large-scale soil moisture data can be helpful in validating remotely sensed precipitation estimates, such as those from GPM, especially in areas that are poorly instrumented [*Crow et al.*, 2011]. In agricultural regions (such as the drought-stricken Central Valley in California), irrigation water from groundwater is often used as supplement to soil moisture. Large groundwater depletion rates are unlikely to be sustainable in the face of increased water use, climate change, and incomplete water management policies [*Famiglietti*, 2014].

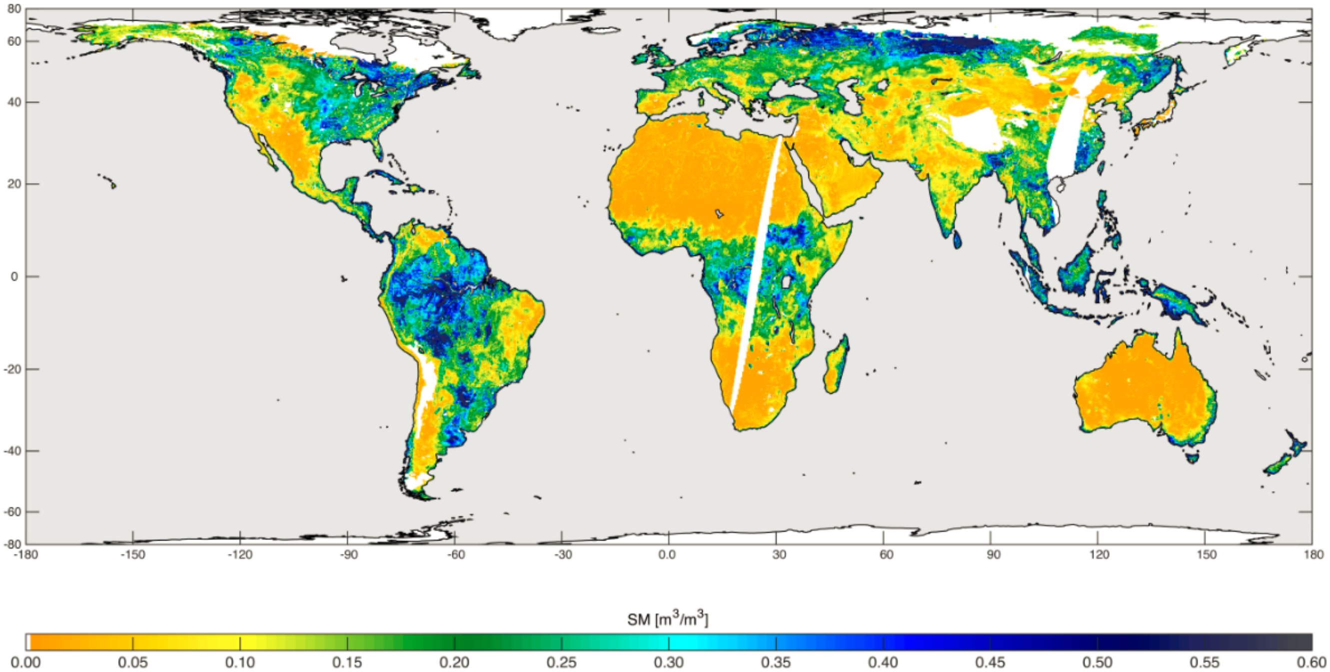

Figure 1. Map of soil moisture measured by SMAP's combined radar and radiometer between 4 and 11 May 2015. These data were taken during SMAP's commissioning phase when the instruments were still turned on and off, so some of the data gaps are not representative of the eventual measurements.

Data from the Gravity Recovery and Climate Experiment satellites (GRACE, launched in March 2002) provides measurements of the total water storage (i.e. the sum of groundwater, soil moisture, surface water, snow and ice cover, and water stored in biomass). The use of land surface models with assimilated soil moisture from SMAP could help tease out with greater accuracy that component of the GRACE signal associated with the amount of water in the unsaturated zone and thus allow more accurate inference of groundwater storage [*Houborg et al.*, 2012].

Another example is in remote sensing of the biosphere, which has recently been revolutionized by the introduction of new methods to isolate chlorophyll fluorescence from atmospheric spectra. Fluorescence is a byproduct of photosynthesis, allowing for the first time direct remote sensing measurements of the photosynthetic flux (gross primary productivity) instead of the indirect measurements of greenness state that are currently used in indices such as NDVI and EVI. Fluorescence measurements have already shown that land surface carbon cycle models underestimate crop productivity in several regions by more than 50% [*Guanter et al.*, 2014]. Although individual observations of fluorescence are very noisy, the 2014 launch of the NASA Orbiting Carbon Observatory – 2 (OCO-2) has enabled measurements at higher spatial, temporal, and spectral resolution which will significantly reduce the amount of averaging needed to reduce noise [*Frankenberg et al.*, 2014]. The combination of OCO-2 data and SMAP data could be used to address a variety of questions about the effect of water availability on ecological functioning. A call has been made for a virtual mission combining the two datasets and the creation of a fused data product [*Stavros et al.*, 2014].

Remote sensing provides a path forward towards understanding large-scale variability in the water cycle around the globe, especially in under-studied regions and at scales that are hard to cover using ground-based sampling. When paired with data from other earth-observing satellites, SMAP data will allow for a range of hydrological and geophysical studies. Furthermore, since climate change, land use change, and human population growth are leading to increasing strains on freshwater and other ecological resources, hazard prediction and monitoring are more important than ever. Soil moisture and freeze/thaw data have a large range of such applications and are only scarcely available today. As a result, the data produced by SMAP are certain to be invaluable to the hydrological community and beyond.

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Joseph. B. Franzini, Engineer, Stanford Professor and Water Resources Expert Dies at 94

Joseph B. Franzini, Ph.D., P.E., F.ASCE, Professor Emeritus of Civil Engineering at Stanford University, and an expert on fluid mechanics and water resources passed away on April 15 in Palo Alto, California. He was 94.

Dr. Franzini was born in Las Vegas, New Mexico and moved to Pasadena, California, where he earned his B.S. and M.S. degrees in Civil Engineering from the California Institute of Technology. Graduating in the midst of World War II, he immediately followed college with Navy service. He went on to serve during World War II as a Lieutenant Junior Grade, and worked in the communications center of the Battleship USS New York. He saw action throughout the Pacific Theatre, including the Battles of Iwo Jima and Okinawa.

After the war, Franzini married his sweetheart Gloria Place, and they moved to Palo Alto while he pursued his PhD in Civil Engineering at Stanford University. He was hired by the Civil Engineering Department, and taught fluid mechanics, and water resources engineering. He continued on the Stanford faculty for 36 years, rising to Professor, and, for many years, Associate Head of Civil Engineering. He is co-author of the widely used textbooks, Water Resources Engineering and Fluid Mechanics With Engineering Applications. The water resources book, which is used throughout the world, is recognized as one of the most authoritative technical publications in its field.

For over 30 years, Dr. Franzini served as a special consultant to George S. Nolte and Associates, a civil engineering firm in San Jose. Franzini worked on many water projects in California and served as a consultant to many government agencies and private organizations, both in this country and abroad. His experience in professional practice added considerably to the scope of his teaching, as he could bring real-world problems and their solutions into the classroom. In his teaching, he always stressed practicality and professionalism. He encouraged his students to participate actively in professional societies, to pursue registration as professional engineers, and to employ the highest ethical standards.

In addition to AGU, Franzini was a member of the American Society of Civil Engineers, the American Society for Engineering Education, and the American Institute of Hydrology. In 1994, Dr. Franzini received the Ray K. Linsley Award from the American Institute of Hydrology honoring "the accomplishments of a giant in the field of hydrology." The same year, he was inducted into the Silicon Valley Engineering Council Hall of Fame for his professional accomplishments.

Dr. Franzini was a man of simplicity and common sense, dignity, and family devotion. He is survived by his wife Gloria, his adult children J.B., Robert, Marilyn, and Cheryl, five grandchildren, and four great-grandchildren.

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