December 2017

# Newsletter

## Hydrology Section

## In this Issue



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American Geophysical Union

# From the Section President

Jeffrey J. McDonnell (University of Saskatchewan)

It's a pleasure to welcome everyone to the Hydrology Section (HS) Fall Newsletter. AGU is less than a month away and the Hydrology Section is abuzz with activity. I want to celebrate a few things with you in this newsletter and then update you on developments for the Fall meeting in New Orleans. The newsletter then follows with reports from our Executive with contributions from the President-Elect, Secretary, WRR Editor-in-Chief, Student Sub-Committee Chair and then write-ups from some of our recent AGU Hydrology Section Fellows and award winners. Lastly, you will see a very useful report led by Jay Famiglietti that I commissioned on communication within our section. As always, I want to thank Jaivime Evaristo for doing such a great job assembling all this material in the newsletter and maintaining the Hydrology Section web page.

**Words of thanks:** Thanks go to the Hydrology Section Executive Committee (Scott Tyler (President-Elect), Charlie Luce (Secretary), Casey Brown (Program Committee Chair), Niels Claes (Student Sub-Committee Chair) who have been working very hard on our collective behalf. To give you some behind-the-scenes insight on all this, Scott sits on the AGU Council Leadership Team and represents our interests exceptionally well there. He also works closely with me on several special projects as well as Chairing the Fellows Selection Committee for our section. Charlie manages two key committees (Outstanding Student Paper Award OSPA and the Student Travel Grant Committee) and manages our finances—no small feat for a section as large as ours. We're well into the black and we're planning on spending some of our cash reserves on AGU Centennial activities (for kick off in DC in 2018 and the main celebration in San Francisco in 2019). Casey Brown and his team have done the Herculean work of arranging our Fall meeting sessions for this year. Casey's deft hand with managing the new conference center and all its dynamics are hugely appreciated. Niels and his team are not only leading our section but are helping the Union understand that student ownership in student activities creates early career leadership that will shape our community. Billy Williams at AGU tells me that our Hydrology Section Student Sub-Committee is the most active in all of AGU. I applaud these efforts and am working on ways to further empower Niels and his team with new resources.

**Technical Committee Updates:** We continue to have quarterly WebEx calls between the Hydrology Executive and the Technical Committee Chairs (Holly Michael, Joseph Alfieri, Marc G. Kramer, Kaveh Madani, Shirley Papuga, Sander Huismann, Pierre-Emmanuel Kirstetter, Theresa Blume, Ming Ye, Teamrat Ghezzehei and Nandita Basu). These meetings are helping us clarify the roles and responsibilities of the Technical Committees (TC) and to engage and re-engage those within our membership with TC-led sessions and events.

As most of you will know, about 8 years ago AGU adopted the open submission processes for sessions and this fundamentally changed many of the TCs' raison d'être. In some ways, we are still trying to find a clear path forward. But the TC Chairs have been thoughtful and enthusiastic about taking on new roles in relation to award nominations (see last newsletter) and session curation under the new rules. We're still not 'quite there' in terms of empowering the TCs to do all that they want to do, and to fulfil the 2015 Ad Hoc Committee on Meetings recommendations for session best practices. **To that end, I have asked Matthew Rodell (NASA-GSFC) to Chair a new Ad Hoc Committee on Technical Committee Roles, Responsibilities and Terms of Reference.** It seems like this is now overdue given some of the changes that we have implemented. He will form his committee in the coming weeks (with some current and past TC Chairs, students, early career scientists and others) and report back to us in the July 2018 newsletter.

Lastly, I encourage all our membership to contact their relevant Technical Committee Chair (e-mails listed at http://hydrology.agu.org/committees/) if you would like to become involved. The TC meeting times and places are listed in the following table—each room can accommodate up to 30 people (names must be submitted to the TC Chairs before AGU week) and I encourage you to reach out to the TC Chairs if you would like to join in on the action.

**Congratulations:** The last newsletter congratulated the winners of the Hydrology Section Awards (we'll celebrate these at the Business Meeting in New Orleans). In this newsletter I would like to congratulate our 7 AGU Fellows within the Hydrology Section: Wei-Jun Cai, Paul Dirmeyer, Susan Hubbard, Yann Kerr, Upmanu Lall, Alberto Montanari, and Richard Vogel. This is an honor bestowed upon <0.1% of our membership. Congratulations to all of them—many of whom are included later in the newsletter under the 'Fellow's Speak' section. I would also like to congratulate the 2017 winner of the Robert E. Horton Medal, Eric Wood of Princeton University. This year, the Union-Level International Award was won by Huub Savenije of Delft University of Technology and the AGU Ambassador Award by Jean Bahr of the University of Wisconsin – Madison. A hearty congratulations to all these Union award winners. The Fellowship recognition and the 3 Union awards will be presented at the Union level awards ceremony on the Wednesday of AGU week.

| Technical Committee Meetings 2017 | | | |
|---|---|---|---|
| **Date** | **Time** | **Event/Function** | **Location** |
| Monday, 11 December 2017 | 6:45AM – 7:45AM | **Ecohydrology Technical Committee Meeting** | Hilton Riverside Hotel, First Floor, Grand Salon -Suite D -Sec 19 |
| Monday, 11 December 2017 | 6:45AM – 7:45AM | **Ground Water Technical Committee Meeting** | Hilton Riverside Hotel, First Floor, Grand Salon -Suite D -Sec 21 |
| Monday, 11 December 2017 | 6:45AM – 7:45AM | **Hydrogeophysics Technical Committee** | Hilton Riverside Hotel, First Floor, Grand Salon -Suite C -Sec 18 |
| Monday, 11 December 2017 | 6:45AM – 7:45AM | **Large-Scale Field Experimentation Technical Committee Meeting** | Hilton Riverside Hotel, First Floor, Grand Salon -Suite C -Sec 16 |
| Monday, 11 December 2017 | 6:45AM – 7:45AM | **Remote Sensing Technical Committee Meeting** | Hilton Riverside Hotel, First Floor, Grand Salon -Suite C -Sec 15 |
| Monday, 11 December 2017 | 12:30PM – 1:30PM | **Hydrological Uncertainty Technical Committee** | Hilton Riverside Hotel, First Floor, Grand Salon -Suite D -Sec 22 |
| Monday, 11 December 2017 | 12:30PM – 1:30PM | **Water and Society Technical Committee Meeting** | Hilton Riverside Hotel, First Floor, Grand Salon -Suite D -Sec 21 |
| Tuesday, 12 December 2017 | 6:45AM – 7:45AM | **Precipitation Technical Committee Meeting** | Hilton Riverside Hotel, First Floor, Grand Salon -Suite D -Sec 22 |
| Tuesday, 12 December 2017 | 6:45AM – 7:45AM | **Catchment Hydrology (formerly Surface Water) Technical Committee Meeting** | Hilton Riverside Hotel, First Floor, Grand Salon -Suite D -Sec 21 |
| Tuesday, 12 December 2017 | 6:45AM – 7:45AM | **Unsaturated Zone Technical Committee Meeting** | Hilton Riverside Hotel, First Floor, Grand Salon -Suite D -Sec 19 |
| Tuesday, 12 December 2017 | 6:45AM – 7:45AM | **Water Quality Technical Committee Meeting** | Hilton Riverside Hotel, First Floor, Grand Salon -Suite C -Sec 18 |

**Fall Meeting:** We had been bracing ourselves for perhaps as much as a 30% reduction in meeting attendance submissions, associated with the past year's White House travel bans and the new location in New Orleans. In fact, what happened was the opposite. This year we received 3,107 abstracts, 300+ more than last year. This represents about 14% of all AGU abstracts

"...our Hydrology Section Student Sub-Committee is the most active in all of AGU."

this year. I won't go into the program details here as space is limited, but I do want to draw your attention to four very important activities within the AGU week. They all relate to building intimacy within our section at the "monster meeting" that is AGU. I hope that you will consider attending each of these events and meeting-up with your fellow section members in each of these venues:

**1. Witherspoon and Langbein Awards lectures (Tuesday, Dec 12, 4-6pm)**
I congratulate our 2017 Witherspoon Lecture awardee, Thorsten Wagner (Bristol University) and the Langbein Lecture awardee for 2017, Robert Hirsch (USGS). This year, the lectures will be back-to-back on Tuesday December 12 at 4-5pm (Witherspoon) and then 5-6pm (Langbein). The lecture hall where these lectures will be given holds 1,000 people and I hope that it will be standing room only! We will transition from these two named lectures to our Hydrology Section Business Meeting, that begins a few steps away at the Hilton at 6:30pm.

**2. Hydrology Section Business Meeting (Tues Dec 12, 6:30-8:30pm)**
We're going 'old school' with the Hydrology Section Business Meeting at this year's Fall AGU. Why? To help our members interact and to build community. We're teaming up with CUASHI this year for a jointly sponsored event. Food and alcohol will flow from 6:30-8:30pm at the Hilton Riverside (Third Floor, St. Charles Ballroom). We'll have an open bar from 6:30-7:30pm, then cash bar for the last hour. We have space for 500 and tickets are going fast. I encourage students to bring their advisors and advisors to bring their students—to use this time for interaction and engagement.

We'll have a short <30 min program that will begin at 7:30pm sharp. This will include:

-Welcome, Jeff McDonnell, President, Hydrology Section
-Welcome, Gordon Grant, Incoming Chair of the CUAHSI Board of Directors
-Citation and Response for the Hydrologic Science Award, Elfatih Eltahir
-Citation and Response for the Early Career Hydrologic Science Award to Amir Agakouchak
-Presentation of the Horton Research Grants to Ravindra Dwivedi, James Knighton and Michael O'Connor
-WRR Editors report from Martyn Clark, Editor-in-Chief
-Concluding remarks by Jeff McDonnell

**3. Catchment Science Symposium (Wednesday, Dec 13, 8am-Noon)**
It's tough to build intimacy among members during a week with 20,000+ participants and >100 HS sessions. One thing we will try out this year is an all-day 'Catchment Science Symposium' on Wednesday December 13th, 8am to Noon. This will be an opportunity for a large number of our section members to spend a ½ day—within the Fall Meeting—in the same room with a larger-than-normal group of colleagues. The goal of the symposium is to be as broad as possible and link to as many of the Technical Committee themes as possible. Jim Kirchner will lead this, fashioned largely on his very successful Catchment Science Symposium, held in previous years at UC Berkeley on the Sunday before AGU. The speakers will be: Chris Soulsby (University of Aberdeen), Beth Boyer (Penn State University), Gianluca Botter (University of Padua) and Laurel Larsen (Berkeley). I encourage as many as possible to attend the event at the Hilton Riverside, Third Floor, St. Charles Ballroom. Contact Jim for details.

**4. Hydrology Section Pod (all-week meeting area)**
We will have one of the 16 'pods' at AGU dedicated full-time to the Hydrology Section. We will use it as a drop-in center for connecting with colleagues and interacting with students. Niels and his team on the Student Sub-Committee will be on-hand there through much of the week to engage with our membership. Please consider using this space as a hang out between sessions and spot to connect with other members of our section.

**A word on oral session convening at the Fall Meeting:** Much has been said over the years regarding how to give a great talk (see a classic called "Guidelines for Giving a Truly Terrible Talk" in a 1984 EOS, Volume 65: 762–763—something that was published in my first year in grad school and something that had an enormous impact on me and my student colleagues). But little is ever said about the job of convening, beyond 'don't ever give a talk in the oral session you are

# From the Section President (continued)

convening'.

I wanted to weigh in with a few thoughts for conveners this year at the Fall Meeting. Half of our membership is comprised of students and early career colleagues. Many of our conveners are doing this for the first time. I applaud these efforts and wish everyone a terrifically successful session. But in the spirit of the 1984 "guidelines", please see below my 'guidelines for being a truly terrible convener":

1. Start the session late and don't worry about keeping on time.
2. Immediately launch into the first talk; simply introduce the speaker by his or her name and read verbatim the talk title as shown on the screen.
3. Do not have a question or two to ask the speaker should the audience be slow to raise their hands.
4. During the transition between talks use the silence for people in the audience to talk among themselves.
5. If a speaker does not show up, use the 15-minute gap for a coffee break.

And, before your session:

6. Don't advertise your session with anyone outside your immediately family.
7. Don't connect to your relevant Technical Committee Chair.
8. Don't email your speakers or communicate with them in any way; it spoils the surprise.
9. Do not rehearse your opening remarks.
10. Do not check out the web sites of your speakers or learn anything about their work.

Of course, conveners should do the opposite of numbers 1-10 above! Your infectious enthusiasm, active chairing and knowledge of your speakers and their talks will help to convey to the audience that they are attending a special event.

The most basic 'job' as a convener is to keep things running exactly on time. AGU is a large meeting where audience members flit from session to session. Coordination of all session times is crucial to make this work. But there is so much more to convening than simple time management. The convener helps the audience know the context for each talk. A few words during speaker change-over can help the audience understand your intended flow. Of course, 'dead air' is the curse of every convener. Therefore, having a question at-the-ready for the end of each talk is critical—and often gives the audience a chance to form their own questions.

The New Orleans meeting could (but hopefully not!) include some 'no-shows' due to last minute visa issues. Conveners need to be ready for this and pre-plan for any last minute eventualities. Think in advance about how to structure a 15-min gap in terms of questions you can go over with the audience. Rather than this being a bad thing, think of it as an opportunity for workshop-like discussion with a focused group. Have questions ready for the audience to answer. Lean on your speakers with pointed questions to get the ball rolling.

Lastly, if you have not already done so, connect with your Technical Committee Chair and get the word out on your session. Communicate also with your speakers now. Remind them about the tight time limit that they will be on and that leaving time for a few questions is the hallmark of a great talk. Tell them about how their talk fits within the overall session theme and why their talk is scheduled where it is so that they too can help the audience connect the dots. Remind them that one slide per minute is the golden rule of a great talk (11 slides max/per presentation).

A good session involves good planning and good talks, but what can make a session great is the conveners' orchestration. A stage presence—with humble confidence and knowledge of the speakers and their material—can turn a set of talks into a beautifully orchestrated event.

I wish all conveners, speakers and audience members a great AGU.

## Hydrology Section Business Meeting and Awards Reception (jointly sponsored with CUAHSI)

DECEMBER 12

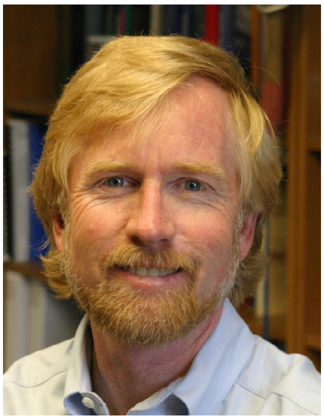
**6:30-8:30 pm**
**Hilton Riverside, Third Floor**
**St. Charles Ballroom**

CUAHSI universities allied for water research

AGU American Geophysical Union Hydrology Section

# From the Section President-Elect

Scott Tyler (University of Nevada, Reno)



It's been almost a year since becoming President-Elect of the section and few less since joining the AGU Council Leadership Team, and it has been a tremendous learning experience. It has been great fun and I really want to encourage those of you who have not yet participated in the various leadership roles of the section to consider it. It really opens your eyes to YOUR Union.

Since the last newsletter, most of my focus has been on the Council Leadership Team or CLT as it is known in AGU slang. I will take this opportunity to share some thoughts and updates. One of the more visible changes that most of you will see at the Fall meeting is a change in nomenclature. For the past year and earlier, the Council and the Council Leadership Team has been discussing and working on developing a common nomenclature for our "engagement" models, i.e. the Sections and Focus Groups. The original concept of Focus Groups was to foster interdisciplinary collaboration and also to serve as launching pads for potential new Sections within the Union. Over time however, the duties, responsibilities and awards of the focus groups grew parallel and equal to those of the existing sections, and there was pressure from some of the Union membership to formally equalize these two nomenclatures. In fact, the current handbook for Sections and Focus Groups makes no distinction for operation between sections and focus groups.

During 2016 and 2017, various proposals and name changes have been brought forward to the Council for discussion, driven by the reality that there is no longer an administrative distinction between the two engagement structures. Polling was conducted beginning in the CLT and then expanding to the entire AGU Council for a common name, and by the September 2017 AGU Council meeting, it was clear from polls and discussions that consensus was approaching. The Council voted electronically, and the results of that vote will be announced to the membership well before our Fall meeting (I have been assured), and even perhaps before this column goes to print. However, watch your email for a "From the Prow" announcement to the membership.

While I have been a strong proponent of Focus Groups to foster dynamic and possibly "term-limited" activities within the Union, and therefore skeptical of the drive to combine our engagement models into one, it is clear that the Focus Groups have evolved administratively to equivalence with Sections. As a result, the adoption of common name for our units is unlikely to have major impact to our Section and its activities. As one of the largest sections in the Union, there are times when our size is a benefit for us; but there are other times when this size proportionality is not maintained. Jeff and I are becoming very attuned to these nuances, and we are working hard to ensure that our Section grows in proportion to our membership where it is appropriate, and that we also continue to support all of our Union colleagues in their sections.

I realize that this change may come as a surprise to some in the Section, but in reality, the discussion has been going on for several years and represents an evolution of the Union. Traditions and names are often difficult to change, but it is important that we recognize when change is coming, and adapt to these changes. As we go forward, I will be working with the Council and our Section leadership to ensure that these changes are positive for both our section and the Union. I look forward to talking to all of you in New Orleans and hearing from you on this topic and the future directions of our Section.

See you all in New Orleans, and yes, "I will sing for Gumbo", but I would not recommend asking!!

> "...it is important that we recognize when change is coming, and adapt to these changes."

# From the Section Secretary

Charlie Luce (United States Forest Service, Boise)

What do you value about science? An odd question you say, for the opening of the Secretary's report, but salient to my chief concern this time of year, the Outstanding Student Presentation Awards. With a new round of OSPA at the Fall Meeting comes the curiosity about new perspectives and ideas, the exhilaration of witnessing the fresh energy, or catching a glimpse of future science. Some may dread the duty and distraction, a *should*, some meet it with indifference, others even voice a certain cynicism, but many look forward enthusiastically each year to an opportunity to engage with new scientists from many different places. Most of us just enjoy the opportunity to welcome a few more people into this big conversation we call science, to share what is important to us, to show how much we enjoy learning, and to explore, in *camaraderie*, the remaining possibilities inherent in still-lingering mysteries of a few new data.

We don't get to walk down the streets of our hometowns and jump into a conversation with a stranger about something really interesting only to gradually notice them reflecting our own values about truth, authenticity, and rigorous logic. When you sign up to judge a presentation, you volunteer for exactly that conversation. Bring what you value about science to the conversation and both of you will walk away with more of it. Energy conservation need not apply.

For science to thrive, it is important that all feel welcome and appreciated for what they bring to the conversation. At a meeting the size of AGU, with thousands of other presentations, it is easy to feel lost and ignored. It is particularly a hard place to feel welcomed and appreciated as a new scientist. New scientists, though are the source of growth and diversity in practicing ranks of scientists, which are critical to the continued relevance of science in society. If you care about the practice of rigorous science, you have to care about the people doing it, and that begins with the newest members. Show them that what they have been working on, and hope to work on more, is important.

This year, it is easier than ever, with 513 student presentations to judge, a 20% increase over last year! We will appreciate any help filling the 1539 judging slots! Sign up early and often. Liaisons and people who indicated an interest in judging have already been notified at least once, and more messages will come until we have secured support for all of the students who have requested it. When judging, please be sure to say something specific in the comments. That is more helpful feedback, and it is essential to identifying the most outstanding presentations.

Please note that previous awardees of the OSPA can be viewed online at http://hydrology.agu.org/awards/outstanding-paper-award-winners/, where there is a link to the presentation title and student. Some students have left notes of gratitude for the recognition, and some have links to their e-posters. I hope it will encourage students to submit their posters online in the future.

This is an appropriate segue to thank the volunteers of the OSPA committee, whom you may have already heard from and should expect to hear from again in the next month. Two of our members are returning from previous service, Alicia Kinoshita (San Diego State University) and Rolf Hut (TU Delft), and besides myself, we have two new members, Matthew Weingarten (Stanford University) and Heidi Asbjornsen (University of New Hampshire). Besides securing judges before the meeting and ensuring that we continue to have judges through the week, this team will work on evaluating the scoring after the meeting.

I'd also like to thank the Student Travel Grant Committee. Who helped evaluate more than 60 travel grant applications over the course of a week. The volunteers this year were Alicia Kinoshita (San Diego State University), Yusong Li (University of Nebraska-Lincoln), Joshua Larsen (University of Queensland), Chadi Sayde (Oregon State University), Bwalya Malama (California Polytechnic State University), Brenda Dolan (Colorado State University), Jon Duncan (Penn

# From the Section Secretary (continued)

State University), Hatim Geli (New Mexico State University), Marios Anagnostou (National Technical University of Athens), and Ming Ye, (Florida State University). Out of this feedback, 36 students from 6 continents (and a few islands) were awarded some support for their travel to AGU this year!

The Hydrology Section budget increased by $11,069 in 2016. Analyzing the budget over the last several years suggests that our regular food and beverage expenses are relatively closely matched to a mix of tickets and basic Union support for food, so that our primary expenses of consequence are awards (mostly OSPA because the major awards have separate endowments) and student enrichment activities. Many years of effort by the Hydrology Section leadership have brought our balance close to $50,000, and we are exploring how to efficiently and sustainably apply donor contributions to support a richer student experience and encouragement of engagement with experienced scientists. This year, the Hydrologic Sciences Student Subcommittee (H3S) proposed several activities with primary financial support from the Union, these activities are being provided additional financial support from the Hydrology Section and Publications to encourage greater participation.

I look forward to seeing many of you in New Orleans!

"For science to thrive, it is important that all feel welcome and appreciated for what they bring to the conversation.... Show them that what they have been working on, and hope to work on more, is important."

# Fall Meeting Updates

Casey Brown (Hydrology Section Fall Meeting Committee Chair)

## Hydrology Section Events

| Date | Time | Event/Function | Location |
|---|---|---|---|
| Tuesday, 12 December | 10:20 - 12:20 | **H22G: Water Data Drought: Addressing Limited Water Demand Data for Research and Policy I (Panel)** | 280-282 |
| Tuesday, 12 December | 16:00 - 18:00 | **Witherspoon and Langbein Awards lectures** | E3 |
| Tuesday, 12 December | 18:30 - 20:30 | **Hydrology Section Business Meeting** | Hilton Riverside, Third Floor, St. Charles Ballroom |
| Wednesday, 13 December | 8:00 - 12:00 | **Catchment Science Symposium** | Hilton Riverside, Third Floor, St. Charles Ballroom |
| Wednesday, 13 December | 18:00 | **Honors Ceremony** | Hilton Riverside, First Floor, Grand Ballroom |
| Wednesday, 13 December | 20:30 | **Honors Banquet** | Hilton Riverside, First Floor, Grand Ballroom |
| Thursday, 14 December | 10:20 - 12:20 | **H42F: Recent Advances in the Hydrologic Sciences I (Panel)** | 280-282 |
| Friday, 15 December | 13:40 - 15:40 | **H53P: Translational Hydrology: Moving from Science to Decisions I (Panel)** | 280-282 |

# Union Lectures of Interest

| Date | Time | Event/Function | Location |
|---|---|---|---|
| Monday, 11 December | 12:30 - 13:30 | **2017 AGU Fall Meeting Presidential Forum: Dan Rather** | New Orleans Ernest N. Morial Convention Center - New Orleans Theater |
| Tuesday, 12 December | 12:30 - 13:30 | **Special Keynote Panel - Why We Are Still In** | New Orleans Ernest N. Morial Convention Center- New Orleans Theater |
| Tuesday, 12 December | 13:40 - 15:40 | **U23A: Climate Science Special Report: An Assessment of the Science Focusing on the United States** | New Orleans Ernest N. Morial Convention Center- E2 |
| Wednesday, 13 December | 08:00 - 10:00 | **U31A: Mitigating Flood Risk and Climate Change Impacts Through Managed Retreat** | New Orleans Ernest N. Morial Convention Center - E2 |
| Thursday, 14 December | 12:30 - 13:30 | **2017 AGU Fall Meeting Agency Lecture: How a Geoscientist can Change the World: Dr. Vaughan Turekian** | New Orleans Ernest N. Morial Convention Center-New Orleans Theater |

# Town Hall Meetings of Interest

| Date | Time | Event/Function | Location |
|---|---|---|---|
| Monday, 11 December | 12:30 - 13:30 | **TH13A Advances in Hydrologic Science by Early Career Scientists: A Discussion of the Publishing Process** | *New Orleans Ernest N. Morial Convention Center- 211-213* |
| Monday, 11 December | 12:30 - 13:30 | **TH13B DOE's Strategic Developments at the Terrestrial-Aquatic Interface** | *208-209* |
| Monday, 11 December | 12:30 - 13:30 | **TH13D: NOAA Modeling Development Forum** | *203-205* |
| Monday, 11 December | 12:30 - 13:30 | **TH13F: U.S. Global Change Research Program (USGCRP) Interagency Working Group on Integrated Observations** | *228-230* |

## Town Hall Meetings of Interest (continued)

| Date | Time | Event/Function | Location |
|---|---|---|---|
| Monday, 11 December | 18:15 - 19:15 | **TH15B: Data Fair Kickoff Panel on Emerging Sources of Scientific Data - Drones, CubeSat, and Citizen Science** | *E2* |
| Tuesday, 12 December | 12:30 - 13:30 | **TH23B: Big Data in the Classroom: Designing digital media tools and resources for diverse learners in K-12 contexts** | *228-230* |
| Tuesday, 12 December | 12:30 - 13:30 | **TH23F: NASA Earth Science Division Town Hall** | *203-205* |
| Tuesday, 12 December | 12:30 - 13:30 | **TH23I: SOCCR-2: The 2nd State of the Carbon Cycle Report, a Sustained National Climate Assessment report encompassing North America and Surrounding Waters** | *280-282* |
| Tuesday, 12 December | 18:15 - 19:15 | **TH25E: NSF Geosciences Town Hall** | *228-230* |
| Tuesday, 12 December | 18:15 - 19:15 | **TH25G: The Agricultural Model Intercomparison and Improvement Project (AgMIP) Town Hall** | *225-227* |
| Thursday, 14 December | 18:15 - 19:15 | **TH45B: Belmont Forum: Funding Transdisciplinary Science for a Sustainable Future** | *252-254* |
| Thursday, 14 December | 18:15 - 19:15 | **TH45I: Upcoming challenges within our community and beyond: 5 minute kickstarters** | *228-230* |

# From the Section Student Subcommittee Chair

Niels Claes (University of Wyoming)

The Fall meeting in New Orleans is getting closer. We have been busy during the past couple of months organizing a couple of events for coming meeting. H3S is organizing 3 **workshops** this year during the conference that provide attendees with opportunities to grow technically and socially within the broader geosciences community. In addition to these workshops, we teamed up with WRR (Water Resources Journal) to demystify the publishing process, from submitting to getting the word out there.

- Workshop 1: Monday Dec. 11th 3pm: **First impressions** count!

*In this practical workshop on introductions and opening conversations, participants are provided with strategies for forging respectful professional relationships. Attendees will practice pronouncing unfamiliar names, learn about respectfully introducing oneself,*

# From the Section Student Subcommittee Chair (continued)

*and how to ask for gender pronouns. Greeting others with the correct name pronunciation and using correct gender pronouns makes professional spaces more inclusive.*

- Workshop 2: Tuesday December 12th, 3pm: Forging successful partnerships between academia, industry, and government: the student's guide to gaining **experience in the non-academic realm**.

*This hour long workshop will feature panelists with a different background (non-profit/ corporation, governmental research facilities and academic institutions). Each panel member will have approx. 5-10 min. to discuss their work, typical job responsibilities, and advice for creating successful partnerships. Following these presentations, students will have the opportunity to ask questions related to these different career paths.*

- Workshop 3: Wednesday December 13th, 3pm: **What next**?!! Keeping motivation and an optimistic outlook!

*The uncertainty of a future beyond graduate studies can be uncomfortable. This session aims to help students prepare for what comes **after graduation** with short presentations from invited speakers in different stages of their hydrologic (academic) career and a Q&A session. Speakers will outline a few difficulties they experienced and the things that keep them motivated to make the struggle worthwhile. Members of the audience will be able to ask questions about the challenges and the career path they chose along with what they would(n't) have done differently.*

- Workshop with WRR: Monday December 11th, 12:30 pm (lunch will be provided): A discussion of the **publishing process**.

*The topics during this lunch session include 1) writing and submitting, 2) reviewing and 3) sharing science and advances in published papers. A panel with scientists, editors and students will be able to give their perspective about these topics and answer afterwards questions that you might have about these different aspects of the publishing process.*

Next to these 3 workshops, we are organizing a town hall meeting and chairing a poster session as well. The town hall meeting will be held on Thursday December 14th evening (6:15-7:15 pm) in the room and will provide students and early career scientists the opportunity to think about the future of the geosciences community. The topics that are covered include: *What challenges do you (fore)see with sciencing in the next couple of years. What direction do you think we should be heading? Do you have an idea of improving the way we live and enjoy our science? How is your "quality of life" as a scientist?*

**We invite everyone** to submit an abstract by December 1st for a short 5 min. talk that shows your perspective on these or other topics that might be relevant for our future and the future of the geosciences community. These short talks should serve as a kickstarter for conversation and lead to an interesting discussion. (https://goo.gl/JfGKmE)

We also chair a poster session on December 13th: *A Scientist's Place: Redefining the Role of Scientists in a Dynamic World*. This poster session features different perspectives on increasing diversity, science communication, and outreach.

All throughout the conference, we'll be challenging students with some fun games via social media and give away small prizes! So keep an eye on our twitter account (@AGU_H3S) and see you in New Orleans!!

# Student Subcommittee: Call for members

H3S is looking for new members to be student leaders of the Hydrology Section. One of the main goals of H3S is to represent AGU early career members and we want to encourage everyone interested to apply to join. The call for new members will be out in December. For more information and instructions on how to apply please check out the H3S website: http://hydrology.agu.org/student/hydrology-student-subcommittee/ or contact the 2018 H3S Chair, Megan Brown (Megan.R.Brown@colorado.edu).

# From Water Resources Research Editorial Board

Martyn Clark (Editor-in-Chief), Jean Bahr, Marc Bierkens, Ximing Cai, Jim Hall, Terri Hogue, Charles Luce, Jessica Lundquist, Scott Mackay, Ilja van Meerveld, Harihar Rajaram, Xavier Sanchez-Vila, and Peter Troch (Editors)

Our mission as WRR Editors is to help the community share major science advances. It's exciting to see the hydrologic sciences community enthusiastically publish their best work in WRR. Since we started our term in April 2017, we've seen a continued increase in the number of submissions (see Figure below). We're continually impressed by the high quality of the papers submitted to WRR. And in fine WRR tradition, we continue to see reviewers habitually go out of their way to provide constructive feedback that help authors improve the science impact of their papers. The efforts to share science go well beyond simply managing the review process – efforts to share science include celebrating major science advances, improving access to data and models, and improving access to WRR papers themselves.

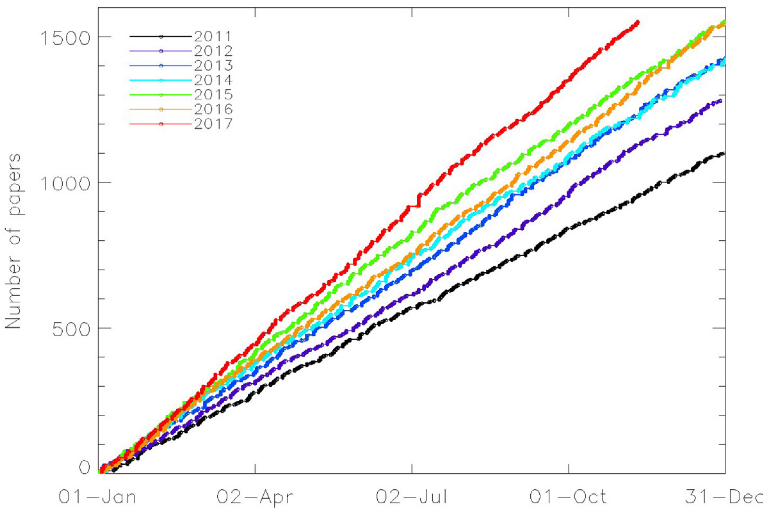



**Figure**. Papers submitted to WRR (2011-2017)

In the last year – at a time when science itself has been under attack – we've seen the hydrologic sciences community step forward with pride, and clearly explain the value of hydrologic science for society. Important contributions in 2017 are [the WRR papers in the "Science is Essential" collection] – these papers celebrate major advances in hydrologic science, show how hydrologic science is essential for society, and illustrate how hydrologic science has influenced policies. We'll continue this celebration at the AGU Fall Meeting this year, where we have a new event to celebrate the

major science advances published in WRR in the last year ([H42F: Recent Advances in the Hydrologic Sciences]; Thursday at 10:20AM). In this session, we have three editor-author pairs that will present major breakthroughs and challenges in specific areas (groundwater, ecohydrology, and catchment hydrology), bookended by two presentations that will give a broader perspective.

We're looking forward to the [Hydrology Section business meeting] (Tuesday at 6:30PM) where we will celebrate science advances with recipients of the Editors' Choice Award, given to about 1% of published articles in the previous calendar year. The recipients of the WRR Editors' Choice award are:

- Fuente, D., J. Gakii Gatua, M. Ikiara, J. Kabubo-Mariara, M. Mwaura, and D. Whittington (2016), Water and sanitation service delivery, pricing, and the poor: An empirical estimate of subsidy incidence in Nairobi, Kenya, Water Resour. Res., 52, 4845–4862, doi:10.1002/2015WR018375.

- Klepikova, M. V., T. Le Borgne, O. Bour, M. Dentz, R. Hochreutener, and N. Lavenant (2016), Heat as a tracer for understanding transport processes in fractured media: Theory and field assessment from multiscale thermal push-pull tracer tests, Water Resour. Res., 52, 5442–5457, doi:10.1002/2016WR018789.

- Masbruch, M. D., C. A. Rumsey, S. Gangopadhyay, D. D. Susong, and T. Pruitt (2016), Analyses of infrequent (quasi-decadal) large groundwater recharge events in the northern Great Basin: Their importance for groundwater availability, use, and

# From Water Resources Research Editorial Board (continued)

management, Water Resour. Res., 52, 7819–7836, doi:10.1002/2016WR019060.

• Menafoglio, A., A. Guadagnini, and P. Secchi (2016), Stochastic simulation of soil particle-size curves in heterogeneous aquifer systems through a Bayes space approach, Water Resour. Res., 52, 5708–5726, doi:10.1002/2015WR018369.

• Saft, M., M. C. Peel, A. W. Western, and L. Zhang (2016), Predicting shifts in rainfall-runoff partitioning during multiyear drought: Roles of dry period and catchment characteristics, Water Resour. Res., 52, 9290–9305, doi:10.1002/2016WR019525.

• Volk, E., S. C. Iden, A. Furman, W. Durner, and R. Rosenzweig (2016), Biofilm effect on soil hydraulic properties: Experimental investigation using soil-grown real biofilm, Water Resour. Res., 52, 5813–5828, doi:10.1002/2016WR018866.

• Wang, S., T. K. Tokunaga, J. Wan, W. Dong, and Y. Kim (2016), Capillary pressure-saturation relations in quartz and carbonate sands: Limitations for correlating capillary and wettability influences on air, oil, and supercritical $CO_2$ trapping, Water Resour. Res., 52, 6671–6690, doi:10.1002/2016WR018816.

• Yang, Y., R. J. Donohue, and T. R. McVicar (2016), Global estimation of effective plant rooting depth: Implications for hydrological modeling, Water Resour. Res., 52, 8260–8276, doi:10.1002/2016WR019392.

Congratulations to all authors for their excellent work!

We're also delighted to introduce a new event at the Fall meeting, a Town Hall meeting with early career scientists (TH13A: Advances in Hydrologic Science by Early Career Scientists: A Discussion of the Publishing Process; Monday at 12:30PM). In this meeting WRR editors and early career scientists will discuss best practices in the publication process and how changes in technology open up new opportunities to share science advances.

As we move forward with WRR we of course recognize that sharing hydrologic science requires not only celebrating major science advances, but also ensuring the accessibility of data, models, and WRR papers themselves. We see that the hydrologic sciences community is becoming much more effective and efficient in sharing data and model source code, where many in the community are putting substantial effort into ensuring that data and models are easy to use. Open data and open models necessarily refocuses the review process – reviewers are now more curious if there is appropriate metadata and documentation, if the model source code is clear and robust, if the test cases are easy to run, and if it is easy to analyze and visualize the data and model output. Open data and open models also goes hand-in-hand with open access of WRR papers – AGU is lowering the hybrid open access fee for WRR from $3,500 to $2,500, making the cost to publish open access articles in WRR more similar to the cost of open access in other journals. This will be implemented beginning with papers accepted and transmitted to Wiley's system starting on 1 Jan 2018, and thus also applies to recent submissions. These changes in open data, open models, and open access will clearly improve the way that science is shared, and hence should have a large impact on the science impact of WRR papers.

As we conclude, we'd like to express our thanks to Ximing Cai, who has decided to step down as a WRR Editor after five years of service. We all appreciate Ximing's thoughtful and rigorous approach in his handling of WRR papers. Please take the time to thank Ximing for his service when you see him at the AGU Fall Meeting.

Ximing is replaced by Jim Hall (director of the Environmental Change Institute at the University of Oxford), who brings much needed expertise in water resources management. We're thrilled to welcome Jim Hall as our newest WRR Editor!

We're all very much looking forward to seeing you throughout the Fall Meeting and learning more about your recent science discoveries. Please feel free to share your ideas, your opinions, your concerns, and your experiences, so that we can improve the extent that WRR advances hydrologic science.

# A Fellow Speaks: Characterizing Integrated Watershed Structure and Hydrobiogeochemical Function

Susan Hubbard, Berkeley Lab

I am honored and thrilled to be selected as an AGU fellow. I sincerely thank my committee who generously dedicated their time and effort to my nomination. I am indebted to my advisors and mentors, including Cahit Coruh, Yoram Rubin, Ernie Majer and Don DePaolo. I consider myself privileged to collaborate with many colleagues who have shaped my research, including the Berkeley Environmental Geophysical Group - I share this honor with you.

Nobel laureate P.W. Anderson's oft-quoted phrase "More is different," aptly describes our Earth system, where interactions and feedbacks between hydrological, geochemical, biological and physical processes occur across vast space and time scales as well as compartments. This is particularly true of shallow terrestrial systems, which provide our water resources, sequester carbon, support our agriculture and energy production and provide many other societal benefits. In these systems, hydrological processes play out over more than 13 orders of magnitude – from hydrogen bonding to flow in regional aquifers. From fractured flow in deep bedrock through evapotranspiration within the vegetative canopy; from terrestrial through aquatic subsystems; and from summits to seas.

While aquifers are recognized as Earth's key functional unit for managing water resources, hydrological processes also mediate biogeochemical processes, which lead to greenhouse gas exchanges with the climate as well as a cascade of effects on down-gradient water availability, carbon and nutrient cycles, and metals loading. Formidable challenges exist in our fundamental understanding of hydrological processes and how they drive biogeochemical transitions across scales. These gaps are magnified when attempting to predict how terrestrial systems respond to and recover from droughts, fire, floods, land use, climate change and other perturbations.

The desire to develop geophysical-based approaches for quantifying watershed structure and hydrological function led me to Berkeley in the 1990s, where I undertook a Ph.D. and became part of a team at Berkeley Lab. This was an exciting period of discovery about the limits and value of geophysical methods for quantifying the shallow subsurface. Through fusing geophysical and other datasets, my Berkeley colleagues and I developed hydrogeophysical approaches to estimate properties such as soil moisture (Hubbard et al., 1997; Grote et al., 2002; Lunt et al., 2005) and hydraulic conductivity (Hubbard et al., 2001), as well as geochemical properties and processes (e.g., Chen et al., 2004; Hubbard et al., 2008; Chen et al., 2012, 2013). These methods improved our predictive understanding of shallow hydrobiogeochemical behavior (e.g., Scheibe et al., 2006), particularly in response to environmental remediation treatments.

The hydrogeophysical community developed in parallel during the 1990s and 2000s. This growth was documented by the increasing number of excellent publications, the recognition among the authors that we were onto something potentially very powerful, and the development of a hydrogeophysical esprit de corp. Several collaborations that I greatly value to this day began during that period. The progression of the field has been well described by publications along the way, from the first hydrogeophysical book (Rubin and Hubbard, 2005) to a recent retrospective of the evolution of the field, published as part of the Water Resources Research 50th Anniversary collection (Binley et al., 2015).

As methods to characterize terrestrial systems have vastly improved over more than two decades of research, the community has become more aware of the complexity of terrestrial systems. However, far from being frustrating, this awareness is leading to new opportunities to develop methods that confront and honor multi-scale, multi-physics, multi-compartment behavior that we now recognize as commonplace.

***Challenges Drive a New Paradigm***

While many of the past hydrogeophysical approaches have focused on using one geophysical method to estimate one property in one compartment of a terrestrial system over 10s of meters or less, new opportunities exist to quantify the connectivity and feedbacks with sufficient resolution, over scales relevant to watershed behavior, and in a tractable manner. The development of several capabilities over the last decade provides a springboard for these new approaches. For example, the Internet of Things and UAV (Unmanned Aerial Vehicle) technologies are changing the way that we characterize terrestrial systems. Community sequencing and bioinformatics are being used to illuminate how the subsurface microbiomes behave when sharing and competing for resources (e.g., Anantharaman et al., 2016). High-performance computing capabilities are allowing simulation of integrated surface-subsurface interactions, including hydrology-driven biogeochemistry - over resolutions and scales relevant to watersheds and beyond. Field observatories, such as the Watershed Scientific Focus Areas supported by the Department of Energy and the Critical Zone Observatories supported by the National Science Foundation serve to nucleate multi-disciplinary investigators as needed to address difficult questions.

Underlying questions are driving new methods to characterize integrated hydrobiogeochemical watershed function, such as: when, where and how small-scale processes drive larger-scale system behavior; and what is the minimum but sufficient information needed to predict behavior at the scale where the system is managed? Our Berkeley Lab environmental geophysics group is advancing several new constructs inspired by these questions, three of which I briefly describe below.

1. **Functional zone characterization approaches** identify regions in the landscape that have unique distributions of hydrobiogeochemical properties that influence system function. We have developed and tested functional zone approaches for several applications using stochastic integration of geophysical and a range of direct measurements. Select examples include the estimation of reactive facies, or coupled physicochemical properties, that are important for flow and reactive transport of subsurface contaminants (Sasson et al., 2012; Wainwright et al., 2014) and the estimation of functional zones and associated property suites that influence greenhouse gas fluxes in an Arctic tundra (Hubbard et al, 2013; Wainwright et al., 2015; Figure 1). The functional zonation approach holds potential for providing minimum but sufficient information about watershed organization and property distribution to predictive models about 'at scale'.

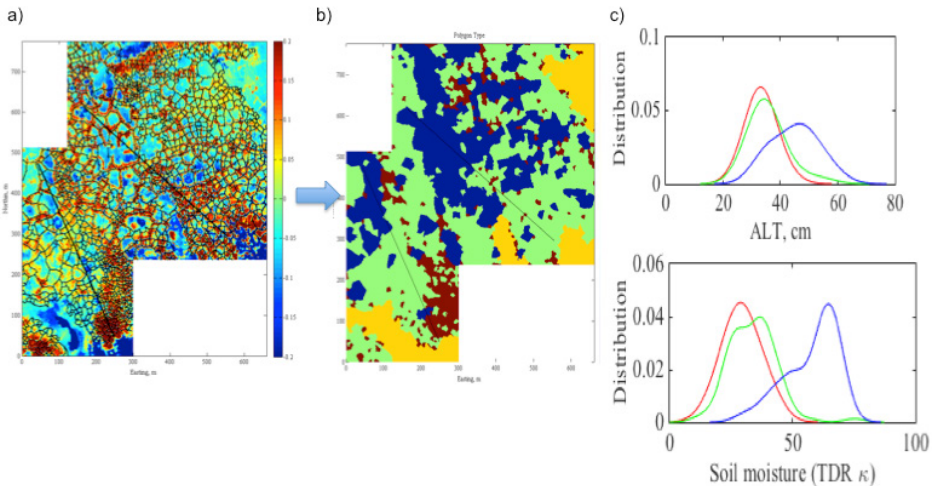



**Figure 1**. (a) Plan view of an Arctic tundra land surface elevation, illustrating presence of thousands of ice wedge polygon features that influence local hydrobiogeochemical behavior; (b) same landscape with interpretation of three geophysically-identified functional zones (colored red, green, blue), each having a unique distribution of above- and below-ground properties that lead to distinct carbon flux behavior; (c) example of two out of many property distributions associated with the red, green and blue functional zones, including active layer thickness (ALT, top) and soil moisture (lower). Modified from Wainwright et al., 2015.

2. Within select functional zones, we have been exploring the value of **networked above-and-below ground systems for monitoring critical zone co-dynamics**, particularly through the deployment of UAV technologies with autonomous point sensors and electrical resistance tomography (ERT). An example is provided by Dafflon et al (2017), who used networked systems to monitor hydrological-geochemical-biological-physical feedbacks across compartments in an Arctic tundra as a function of freeze-thaw cycles (Figure 2). Providing a fantastic stream of diverse datasets in high spatiotemporal resolution, these new monitoring approaches are allowing a window into the critical zone, enabling us to in essence 'watch the

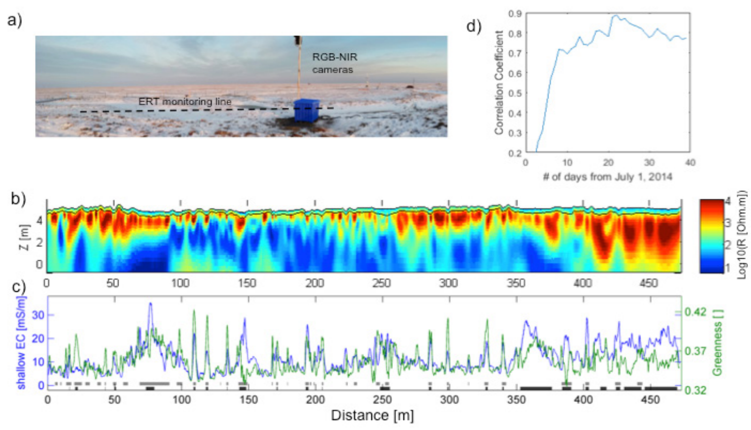



**Figure 2**. (a) Co-location of select instruments that simultaneously and autonomously monitor above-, at-, and below-ground processes in an Arctic tundra (b) an example of one of the datasets: a 2D ERT 500m long transect, which reveals active layer and permafrost vertical variations at one point in time; (c) high correlation between soil electrical conductivity (EC) and vegetation greenness index along the ERT transect at one point in time; (d) dynamic correlation between soil electrical conductivity and greenness index over time at a single location, exhibiting a very high correlation between above and below ground properties during the growing season.

system breathe'.

3. While model-data integration is not a new approach per se, the **assimilation of streaming data into integrated watershed models** is relatively new and is particularly promising. We are finding that such assimilation can greatly improve estimation of properties and holds potential for indicating where conceptual or numerical process representation deviates from actual system behavior. The advance of joint geophysical-reactive transport inversion approaches similarly holds potential for improved predictive understanding of hydro-biogeochemical processes across scales.

***Perspectives for Early Career Scientists***

Each day, I am increasingly excited about the significant scientific challenges that lie before us. For students and early career scientists, I'd like to offer a few perspectives that may be helpful as you develop in your career. Above all, strive to be a leading expert on your research topic. In parallel, take time to fully grasp - and be able to communicate - the broader context and drivers for your work to maximize its impact. Seek opportunities to work as part of a multi-disciplinary team wherever they arise. If you are as fortunate as I have been, such collaborations will not only stimulate you but will drive your research in unexpected ways. Strive to evolve your research efforts in ways that you find most enjoyable, stimulating and rewarding. Consider opportunities to test various professional pathways, which might include academic, national laboratory, industry, or non-profit organizations. The modes of research and expectations may be quite different across these organizations, and it can be illuminating to explore which suit you best. The scientific and technical gaps in our field are plentiful. Given the fraction of waking hours that many of us tend to spend on our research, paired with the wide opportunity to make a substantial contribution to important societal challenges in our field, there is ample opportunity to achieve co-benefits of enjoyment and scientific impact.

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# A Fellow Speaks: The evolution of hydrologic knowledge

Richard M. Vogel, Tufts University

As hydrologists, we all stand on the shoulders of giants. Extraordinary researchers such as Matalas, Fiering, Thomas, Salas, Beard, Hirsch, Dooge, Stedinger, Lettenmaier, Kuczera, Lall, Hornberger, and Hosking and extraordinary consulting hydrologists such as John Schaake, Chuck Howard, Dan Sheer and Morris Root, are just a few hydrologists that shaped my intellectual approach to research and most importantly, created a model for excellence in research, scholarship and hydrologic practice, which I will always aspire to. Excellence in scholarship provides a foundation of hydrologic knowledge, resulting in methods, technology, and solutions to societal challenges. As a young hydrologist I did not understand the potential impact scholarship could have on addressing societal challenges. If I had one lesson to impart to young hydrologists it would be to encourage them to respect, read and contribute to hydrologic literature, because it is the foundation of our 'hydrologic field knowledge' and enables us to address critical societal challenges. As I describe below, the field of hydrology is a very advanced 'field of knowledge' due in part to the unique literature which both supports and defines our field.

Ever since my early attempts as an undergraduate systems engineering student at UVA in 1975 to create a water balance model of the Lake of Tunis on an analog computer and my subsequent attempts as an MS student to calibrate and validate the Stanford Watershed Model on a mainframe IBM computer in 1977, in one of George Hornbergers' classes, hydrology came alive with all its exciting challenges. My subsequent two years of experience as a consulting hydrologist created a window into hydrologic challenges ranging from water supply engineering to stormwater management and hydropower engineering.

From my early experiences in the field of hydrology, It became clear that I needed a very broad range of knowledge and skills to respond to societal challenges in hydrology, thus my PhD under the direction of Jery Stedinger at Cornell University, focused on the critical interdisciplinary subjects for the 'information age' including: decision theory, systems analysis, probability and statistics-- all needed for the solution of most modern societal challenges. Thirty-five years later, I continue to be amazed at how little attention is given to these fundamental interdisciplinary subjects in a typical university hydrology or engineering curriculum. I have been arguing for decades that the theory of probability and the decision sciences provide the foundation for addressing information challenges, much like the theory of mechanics forms a foundation for addressing challenges relating to the physical world. Thus the theory of probability and the decision sciences needs similar emphasis to the theory of mechanics, during the early stages of an engineering curriculum.

Remarkably, I never seem to run out of ideas for research and scholarship to support my enthusiasm. My recent quest is to convince all hydrologists, regardless of their training, of the importance of treating all hydrologic models as having both deterministic and stochastic elements. In spite of the now widespread application of watershed models in practice, ignoring their stochastic elements leads to systematic bias in critical real world applications (Farmer and Vogel, 2016). In a recent paper, I propose that many aspects of water resource design, planning and management that were historically addressed by 'stochastic streamflow models' are much better addressed by combining stochastic and deterministic elements of models into 'stochastic watershed models' (Vogel, 2017). This is especially true in the Anthropocene, when urbanization, agriculture and other forms of development may lead to nonstationary hydrologic processes. Stochastic watershed models are well-suited to solving a wide range of societal challenges, while simultaneously enabling new developments in other disciplines that can be integrated into the solution of those challenges.

I have always been an active observer of the evolution of knowledge in the field of hydrology. Consider, for example, the subfield of hydrology known as flood frequency analysis. Perhaps the first comprehensive treatment of flood frequency analysis began with the textbook summarizing the theory of extremes in 1958 by the statistician E.J. Gumbel, titled "Statistics of Extremes". In that textbook, floods and droughts were the only examples of extreme events (natural hazards) considered. On the one hand, it is unique for a mathematical statistician (such as Gumbel) to address hydrologic problems—few other examples exist. On the other hand, the development of a rich theory of extremes by a mathematical statistician, combined with example applications to our field, even before the advent of computers, have (arguably) enabled the field of flood frequency analysis to evolve well beyond how frequency analysis is applied to other natural hazards. I have noted this fact in several papers in which I was able to transfer basic methods developed in flood frequency analysis to problems relating to earthquakes, wind loads, landslides, and bird and plant extinctions. For example, earthquake engineers and seismologists do not appear to have read or appreciated developments in the field of statistical hydrology which could have a direct impact on their own field. A wealth of research from the 20th century documents why it is advantageous (and now standard practice) to pool regional information in flood frequency analysis using what is known as the 'index flood' method. Although an analogous 'index earthquake' was introduced to their literature in 2007, it has received little or no attention. Similarly, dozens of rigorous studies document the conditions under which it is more favorable to employ the series of annual maximum floods or earthquakes, in favor of exploiting the longer data series based on all of the peak events over a threshold. One can easily show that the famous and widely accepted Gutenberg-Richter model of earthquake frequency is mathematically equivalent to the two parameter Gumbel distribution. If seismologists and earthquake engineers were to fully understand developments in flood frequency analysis over the last half century or more, it is likely that they would discard their Gutenberg-Richter/Gumbel model in favor of a generalized extreme value (GEV) distribution, which is a generalization of the extreme value distributions introduced by Gumbel in 1958. Note that the GEV model can exhibit an upper bound, consistent with our physical knowledge of earthquakes, unlike the Gumbel distribution which has no upper or lower bound. I am certain that numerous other fields focusing on the statistics of natural hazards could learn a great deal from the highly evolved subfield of hydrology known as flood frequency analysis. Hydrologists can not only learn from statisticians, hydrologists can also contribute to fundamental advances in the field of mathematical statistics. For example, contributions by Hosking on L-moments, and Stedinger on the GEV distribution, are included in the Encyclopedia of Mathematical Statistics and are now commonly applied by both statisticians and hydrologists. Apparently, it is just as rare for mathematical statisticians to apply their theoretical developments to hydrologic problems as it is for hydrologists to produce research that ends up being used by mathematical statisticians. Still, both types of knowledge transfer are essential to the evolution of a field of knowledge.

Perhaps the most important message I want to convey relates to the apparent, yet increasing lack of attention that is given to some of our seminal hydrologic field knowledge. On the one hand, I have provided a brief overview of how and why our "hydrologic field knowledge " may have evolved beyond analogous field knowledge relating to other natural hazards. On the other hand, there are numerous critical developments in the field of hydrology which appear to be forgotten, and this phenomenon, if left unaddressed, could lead to a fundamental breakdown in the evolution of our "field knowledge". One striking example of this relates to our understanding of the value of parsimony in hydrologic models. Seminal scholarship on this subject includes the 1993 paper by Jakeman and Hornberger titled "How Much Complexity Is Warranted in a Rainfall-Runoff Model?" and the 1975 paper by Slack, Wallis and Matalas titled "The Value of Information to Flood Frequency Analysis". Both of these papers demonstrate that simple, parsimonious models, which may not have an entirely correct representation of all the relevant physical processes, may yield improved hydrologic predictions. The value of parsimony in hydrologic modeling can only be fully understood and appreciated, within the context of the concepts of robustness, resistance, and efficiency; concepts nicely outlined by Kuczera in his 1982 paper titled "Robust flood frequency models". The fact that for nearly half a century, our field has clearly documented and demonstrated the value of parsimony in hydrologic modeling, provides further evidence of the advanced state of evolution of the field of hydrology. What concerns me is the literal proliferation of complex hydrologic modeling tools, which claim to offer solutions to many pressing societal challenges resulting from the myriad of anthropogenic influences on hydrologic processes.

Simply advancing new and more physically realistic approaches for handling nonstationarity, complexity, uncertainty and surprise, or the impact of climate change, urbanization, and other anthropogenic influences, will not necessarily lead to improved decisions. Robust solutions to 'new' societal challenges will only come from innovations and scholarship which are consistent with the seminal concepts and practices introduced to our field decades ago—which enabled our field of hydrology to evolve beyond other related disciplines. Let us not forget our rich hydrologic literature, nor those giants upon whose shoulders we will always stand. I am thankful to those giants because without them, I would never have become an AGU Fellow. Finally, let me dedicate this passage to my dear friend and colleague, Tim Cohn, who this year, lost his life, but whose ideas will live forever, through his seminal hydrologic scholarship.

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# A Fellow Speaks: We did it wrong, but we got here anyway

Paul A Dirmeyer, George Mason University

I am deeply honored to be elected a Fellow of AGU. I thank my colleagues for their support during the nomination process, and I truly appreciate my good fortune to have been placed in the path of so many wonderful opportunities throughout my career. All my years at COLA (the Center for Ocean-Land-Atmosphere Studies) as it moved from academia to NGO and back to academia, have served as a bottomless resource in so many ways. For most of that time I have represented the "L" in the acronym, which necessitates a highly interdisciplinary approach to science, and demands one become at least partially literate in many different fields. I take it as a testament to a balanced approach across Earth system science, and a backhanded compliment, that many colleagues consider me an expert in the things they don't do.

I have been active in science for nearly three decades, starting as an undergraduate hourly employee doing programing, graphics and analysis for Professors Jim McGuirk and Aylmer Thompson at Texas A&M University. When searching for graduate schools, I chanced upon the then newly-established COLA leading me to the University of Maryland to pursue an interest in numerical modeling. J. Shukla and the scientists there were a gateway to global climate modeling and an introduction to so many luminaries. My background was in meteorology, but my interest turned to land-atmosphere interactions thanks to people like Carlos Nobre and Piers Sellers.

Three decades is long enough to witness some perceptible evolution of scientific history. In the early 1990s, it was already recognized that land surface states could affect the atmosphere on a range of time and spatial scales. Sub-seasonal to seasonal anomalies in land surface states like soil moisture and snow cover, as well as long-term changes in vegetation cover, were accepted to be the most important. However, outside of a smattering of fairly simple modeling studies, the concept remained mostly hypothetical with little in the way of observational evidence. Furthermore, the theory of land-atmosphere interactions was being developed in a fragmented fashion within multiple disciplines that interacted only sporadically. Scientists in the fields of meteorology, hydrology, ecology, soil science, agronomy, civil and environmental engineering were all taking different approaches, with vastly different techniques and jargon sometimes even within the same discipline.

Yet today we find ourselves in the golden age of the study of land-atmosphere interactions. We are at the cusp of fruitful application of our science to operational monitoring and forecasting. It has taken much longer to get here than it should have. The reason is the study of land-atmosphere interactions has evolved backward to the usual progress of science. Science typically advances from observation of a phenomenon to formulation of hypotheses about the processes behind it, observational studies, conceptual and numerical modeling culminating in accepted science. In our case, the numerical models of the land surface came first, driven by the need to supply lower boundary conditions to burgeoning weather and climate forecast models. This happened when there were precious few in situ observations of land surface states, never mind field studies of land-atmosphere interactions. Remote sensing had severe limitations, and satellite measurements of soil moisture were happenstance, teased from data of instruments designed to measure other things. The last two decades have been a slow scramble to build the foundation after the house, so to speak, but now we are on solid ground.

In situ and remote sensing measurements of the land surface are maturing. There is a global network of flux towers that provides linked measurements of near-surface, surface and subsurface aspects of the water, energy and carbon cycles at hundreds of sites around the world, but still there are large areas of the globe where measurements are few. Intensive long-term field sites have expanded measurements including lower troposphere states, subsurface hydrology, and side-by-side comparisons of multiple instrumental approaches. Satellites are providing ever more accurate estimates and covering more components of important climatic cycles. Now we are going back and confronting our models and ideas of how land-atmosphere interactions occur, and their importance in weather and climate.

Thanks to the efforts of national and international collaborations through organizing bodies like the Global Energy and Water Exchanges project (GEWEX), a more complete, process-based picture is emerging. We are finding though a combination of observational analysis and modeling studies that there are three ingredients necessary for variations in the state of the land surface to have a significant feedback on weather and climate, particularly extremes. First, there must be sensitivity of the atmosphere to anomalies at the land surface. This sensitivity can exist in one or more pathways, namely through the water and energy cycles, where a change in land surface states such as soil moisture, snow or vegetation cover correlates significantly to changes in surface fluxes and atmospheric states. Areas of sensitivity vary seasonally, spatially, and are modulated in extreme situations and climate change. Second, there must be sufficient variability or magnitude of land surface variations for meaningful manifestation of signals in the atmosphere. For instance, evaporation is highly sensitive to soil moisture in the Sahara desert, but as there is rarely rain, soil moisture variability is very low (like the mean), and the sensitivity is rarely expressed. Third, land surface anomalies must persist long enough to have a consequential impact on weather or climate. For extreme weather events, one or two days of persistence of a large soil moisture anomaly may be sufficient; for something like a drought, anomalies may need to last for weeks or months.

In terms of a positive impact of the study of land-atmosphere interactions on society, the proverbial “low-hanging fruit” seems to be in operational forecasting in the sub-seasonal range, longer than conventional deterministic weather forecasts (about a week) but shorter than seasonal probabilistic climate predictions. The persistence or memory of land surface anomalies is in this range, typically from a couple weeks out to around two months. The information in land surface anomalies has not been widely exploited for weather and climate forecasting; this is likely to be where the greatest impact will occur during the next decade.

We are finding that just as the central and eastern tropical Pacific is a critical location for ocean-atmosphere interaction that affects weather and climate, there are “hotspots” of land-atmosphere coupling and feedback. These hotspots are typically found over continents in transition regions between arid and humid regimes, and they express most strongly in the mid-latitudes between late spring to early fall, and in the subtropics over monsoon regions outside of the core rainy season. Over North America, this region corresponds to the Great Plains. Globally, these hotspots largely correspond to the most important and productive agricultural belts where grains are grown. This has serious socioeconomic implications, as it means these sensitive areas are also the locations where mankind exercises some of the greatest manipulation of the Earth’s vegetation. Modeling studies are also suggesting that these hotspot regions will grow in size in a changing climate and will be active over a greater portion of the seasonal cycle, potentially strengthening the consequences of land use change and land surface extremes on climate. We are far from done with this topic. AGU, with its broad umbrella covering so many branches of geoscience relevant to this problem, will be a nexus for land-atmosphere interaction research into the future.

# A Fellow Speaks: The exciting beauty of hydrologic patterns

Alberto Montanari, University of Bologna

I was born and grew up in Italy, a country where few people were fluent in English during my youth. By chance I had the opportunity to complete a Ph.D. and, later on, again by chance I became assistant professor at the University of Bologna and then my academic career began. By chance I had a Ph.D. advisor, Renzo Rosso, who was fascinated with international literature, a rarity in Italy in the eighties, and therefore it was suggested that I learn English and attend international meetings. My first conference was the assembly of the European Geophysical Society (EGS, now EGU) in Grenoble in 1994, where I first met Demetris Koutsoyiannis. After my talk he asked me a question that I did not understand at all, and therefore I gave a random reply. Later on Demetris provided me with a great deal of inspirational advice, even if we often disagreed. Which is good, because disagreement is an essential ingredient for scientific development.

The above experiences suggested to me that life evolves along a pattern that is partly defined by our will but is ultimately shaped by randomness. As a consequence, I had the intuition that the same may be true for Earth system processes. However, I was a naïve young researcher and therefore I concluded that the idea was nonsensical.

The main goal of my research has always been to improve the performance of hydrologic models. Like many others, I had the dream to build the perfect model, one that could predict future trajectories for an unlimited lead time. I quickly realized that this is an impossible target, due to the presence of uncertainty. I made several efforts, tried dozens of models and calibration techniques in the attempt to eliminate uncertainty. After about a decade, I became convinced that uncertainty can be reduced but will never be eliminated. Therefore, I realized that my initial idea was not so wrong: randomness, which implies uncertainty, is a fundamental component of geophysical processes. The key challenge is to understand to what extent randomness, and therefore uncertainty, can be isolated by improving models and methods. In other words, I realized that causality and casuality should not be considered dichotomous but should rather be integrated in a flexible modeling framework.

Therefore, my dream turned from the perfect model to the model that can efficiently integrate both randomness and deterministic laws analogous to some principles of physics. I started considering randomness as an exciting and challenging component of Earth and space processes to be understood, isolated and finally assessed. I realized that uncertainty is not a problem if efficiently estimated and communicated. Humans, in particular decision makers, are used to dealing with uncertainty in their daily life. In fact, one fundamental lesson I learned is that we do not need to look for fancy approaches to investigate uncertainty. We should rather search for efficient methods to rigorously assess the behavior and impact of randomness. There are several possible ways to get to target: I believe that the most efficient approach is through statistics and probability.

When trying to isolate randomness, I was immediately fascinated by patterns in signals that we still cannot understand and explain. In particular, I was attracted by long term cycles in geophysical processes, which occur at multiple time scales. For what reason was Europe warmer than today, during the medieval period? What was the cause of the Little Ice Age that occurred afterwards, up to the mid 18th century? Was it due to low solar radiation, heightened volcanic activity, and changes in the ocean circulation, or other causes? How can we explain the drought period that occurred from 1940 to 1950 in Italy?

If we look at the time series of several rivers we do see fascinating patterns that we cannot explain, which are probably due to intrinsic and possibly random behaviors of the underlying processes. Figure 1 shows a 3-D representation of the daily flows of the Po River (the longest river in Italy, with a watershed area of about 70.000 km2 ) from 1920 to 2009 (see Montanari, 2012, where an animated version of the Figure can be downloaded). Here, river discharge is plotted on the vertical axis, while year and calendar day are represented on the horizontal axes. The surface was smoothed in order to make it more readable. In detail, a moving average and a Gaussian filter were applied. The width of the filter window is 25 and 10 adjacent values along the intra-annual and inter-annual direction, respectively. Figure 1 shows the presence of strong seasonality, as well as singularities in the inter-annual direction that are extended well beyond the filter width. In particular, the summer drought looks exacerbated in recent years, but a similar drought period, as mentioned above, occurred from 1940 to 1950. The singularity arising from the occurrence of two major floods in 1994 and 2000 is visible as well. After 2000 no major floods occurred along the lower course of the Po River. It is interesting to note the presence of other singularities like, for instance, the spring peak occurring around the end of March which was more pronounced in the years from 1950 to 1980, approximately.

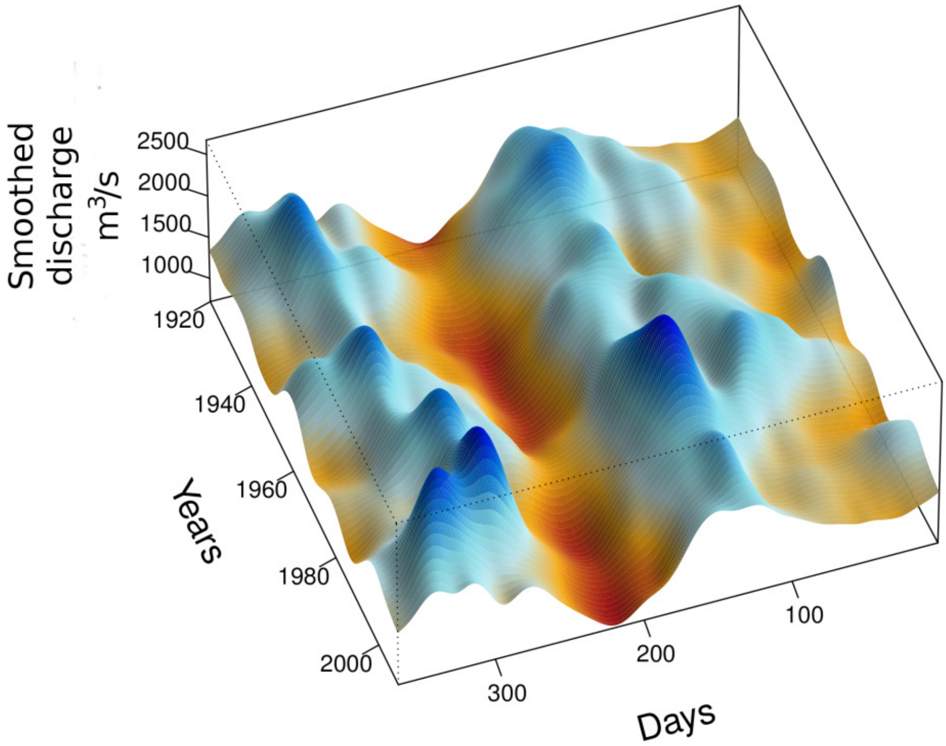


**Figure 1**. 3-D representation of the daily flows of the Po River from 1920 to 2009 (Montanari, 2012)

Several contributions in the literature highlighted that these singularities are probably due to the above mentioned cyclical behaviors, and it was clearly shown that they occur at multiple time scales. An interesting example, which is excellently illustrated by Marani and Zanetti (2015), is the precipitation series of Padua, the longest daily rainfall record available. Understanding the reason for these patterns and their distribution is an exciting endeavor, which opens the door to future research and has noteworthy implications in water resources management and engineering. In fact, the first researcher who realized the implications of cyclical behavior of river flows on water resources management was an engineer, Harold Edwin Hurst. While he was working on the design of reservoirs along the Nile River, he discovered the so-called "Hurst Effect" (Hurst, 1951), which implies long term variability of the considered signal. The Hurst Effect was later termed "Hurst-Kolmogorov behaviour" by Koutsoyiannis and co-workers (Koutsoyiannis, 2003; Koutsoyiannis and Montanari, 2007; Koutsoyiannis et al., 2009). The exciting story of H.E. Hurst is described in O'Connell et al. (2016). Modeling the Hurst Effect in hydrological records was the subject of my Ph.D. thesis (Montanari, 1997).

Now, more than 60 years after the discovery of the Hurst Effect, I believe that several research questions still remain regarding long term patterns of Earth processes. The compelling need to explain deterministically the dynamics of climate and the distribution of water resources, for the sake of obtaining long term predictions, has led several scientific disciplines to neglect what cannot be modeled through a deterministic model (or to assume that it is negligible). Now it is time to reconsider randomness. We need to remind ourselves, and to make clear to students, that there is still much that we cannot explain deterministically in Figure 1, and that those unknown elements may remain unknown or, in other words, they are random and possibly more relevant than the deterministic component. I believe that recognizing the unknown and random dimensions of hydrologic patterns provides a fascinating perspective, that will lead to exciting discoveries that, no doubt, the new generation will make in the forthcoming decades. I am convinced that we need to work for reducing uncertainty, and that the goal can be achieved by improving deterministic representations. However, recognizing the role of randomness is the essential ingredient for a successful strategy. More details on my vision above are given in Montanari (2012), Montanari and Koutsoyiannis (2012) and Bloeschl and Montanari (2010).

# A Fellow Speaks...Alberto Montanari (continued)

I am extremely honored to be elected fellow of AGU. During my life, I received a great deal from scientific associations. I owe to them aspects of my education, stimulating ideas and personal growth. I had the opportunity to meet many extremely interesting people, who still amaze me at every meeting. Some of them became my close friends. I am particularly indebted to AGU, EGU and IAHS. The Hydrology Section of AGU is like my second home. Water Resources Research has always been my dream journal and I felt like the dream became true when I had the opportunity to work as Editor in Chief of the journal from 2013 to 2017. I am extremely grateful to the colleagues who nominated me and supported my nomination, and to the selection committees for their voluntary and professional dedication.

Finally, I would like to dedicate a special recognition to my friend Tim Cohn, who is no longer with us. I first met him at an AGU meeting. He was for me an example to follow, both for his attitude toward his research and the way he dealt with his challenging illness.

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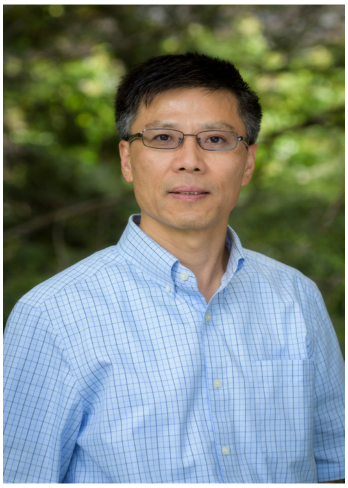
# A Fellow Speaks: the coupling between terrestrial exports and ocean responses is tightening


Wei-Jun Cai, University of Delaware

It is a tremendous honor for me to be elected a Fellow of the American Geophysical Union. I sincerely thank my colleagues for their efforts to nominate and support me. When I was in 6th or 7th grade, my class went to a cinema and watched a "science education" movie (a short film shown before a drama, which was a practice in China in early 70s since most families at the time did not own television sets). The film talked about how the Himalaya Mountains rose from the sea floor in the distant geological past with marine fossils on top of the mountains and that they were still rising today. Shocked and fascinated, I was immediately attracted to science (and never doubted my choice through good and bad times). Throughout my career, I have only studied one element— carbon — and focused on its inorganic species in water (dissolved inorganic carbon or DIC). I once joked with a colleague and friend whose research field had evolved from organic geochemistry to geomicrobiology and beyond, that I am a simple person and will only study one simple molecule, carbon dioxide ($CO_2$). But of course, $CO_2$ is not so simple and its cycle in the earth system is quite complex. When asked why I want to study the carbon cycle I always give the same reply (whether I'm asked by academic colleagues, neighbors, friends or family): carbon is the currency for measuring the rates of biological production and respiration, and $CO_2$ is a greenhouse gas that we must care about. I also tell them the fun part of my research is that I get to work with a broad spectrum of scientists including geochemists, biologists, hydrologists and climate scientists, as well as with social scientists and policy makers.

The scientific debate over the carbon source/sink status of the coastal zone is critically important, given that coastal systems are a key component of the global cycling of carbon and nitrogen. Natural processes such as weathering and erosion, combined with anthropogenic processes such as land-cover/land-use change (LCLUC), rivers and estuaries provide a central link between the land and ocean margins. Understanding this linkage is fundamental to understanding the feedbacks and interactions between terrestrial and marine cycles of carbon and other elements. The magnitude of change of carbon and nutrient export from land to coastal regions and the sensitivity of change to natural and anthropogenic drivers is uncertain, and has been identified as a major gap in our understanding of the global carbon budget (Cai 2011; Bauer et al. 2013; Huang et al. 2015; Tian et al. 2015). In the fall meeting, with other colleagues, I will organize a session to synthesize research activities that address the impact of climate variability, climate change, and LCLUC on the transport and cycling of carbon and nitrogen to and within the coastal oceans through the use of field observations, satellite data and models (I hope to see some of you there).

One question I am pondering is whether the coastal ocean CO2 sink has increased or decreased in recent decades and how is this likely to change in the coming decades (Cai 2011; Bauer et al. 2013; Wang et al. 2017b). The greatest challenge to decoding this coastal CO2 trend is the "noise" signal introduced by the wet and dry variability of the terrestrial hydrological cycle. As coastal ocean mooring CO2 sensors have become more popular in the past decade, two to three decades of cruise-based data have now been collected, and land-ocean coupled models have become more sophisticated and realistic, I believe we are ready to address at least the first half of this important question.

One well-known ocean response to terrestrial nutrient inputs is coastal ocean eutrophication and the associated hypoxia in bottom or downstream waters. Coastal ocean hypoxia areas or Dead Zones (so-called, as they have detrimental effects on marine organisms and ecosystem health) are increasing globally and have spread from developed countries to developing or emerging nations worldwide (Rabalais et al. 2014). Another recognized ocean response to land and atmospheric changes is ocean acidification. Anthropogenic CO2 has increased more rapidly in the atmosphere since the Industrial Revolution than natural CO2 increase in any period over the last ~800,000 years. Consequently, the uptake of CO2 by the ocean has altered surface seawater acid-base chemistry, lowering pH by about 0.1 unit and carbonate mineral saturation state by 0.5 units. This process, known popularly as ocean acidification (OA) for over a decade, will continue to decrease seawater pH by another 0.3 units by the year 2100. OA is expected to have detrimental effects on the health of marine organisms and ecosystems and alter the associated biogeochemical processes. It is only more recently known that extremely low pH can result when the two sources of CO2 (from fossil fuel and from organic matter decomposition) are in the same water. Thus, there are still challenging geochemical issues to be explored, and biologists and ecosystem scientists will love to hear our stories of this not so simple molecule (Cai et al. 2011, 2017; Sunda and Cai 2012; Hu and Cai 2013; Wanninkhof et al. 2015).

The land-atmosphere-ocean coupling is not limited to the coastal zone, and it even extends to the Arctic Ocean basins! The Arctic Ocean and its surrounding lands have experienced rapid changes related to global climate warming. On land, these changes include reorganization of the hydrological cycle, expansion of temperate ecosystems into subpolar/polar regions, and mobilization of terrestrial carbon pools. In the ocean, changes include atmospheric and ocean warming, sea-ice loss, increased freshwater accumulation, and likely high biological production in exposed surface waters and under thinner sea-ice. It has been an amazing experience to witness the rapid changes of the CO2 system in the Arctic Ocean, visiting as part of the Chinese National Arctic Research Expedition (CHINARE) every two years since 2008. During our

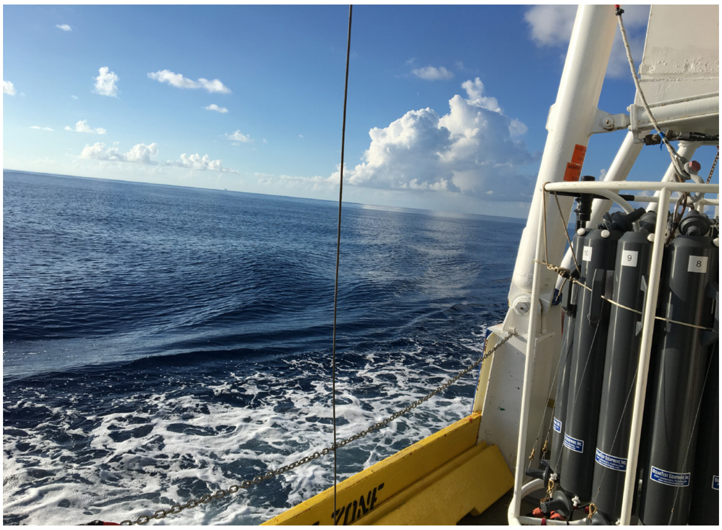


**Photo**: RV Pelican (Gulf of Mexico; July 10, 2017)

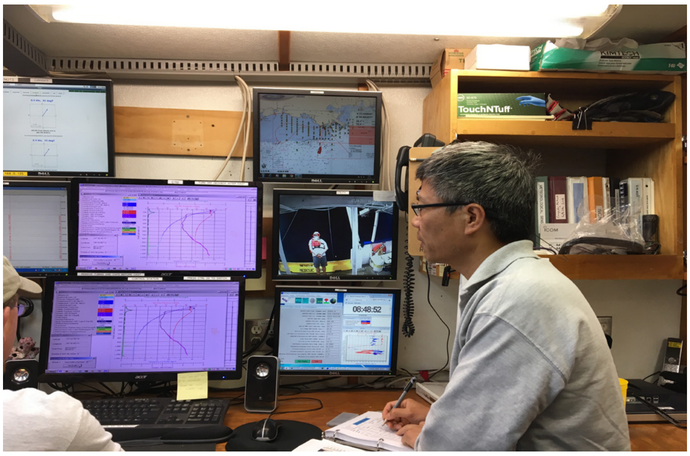



**Photo:** Cai at work inside the Tech Room, RV Pelican

summer studies between 2008 and 2016, we found an expansion of the high pCO2, low pH and low carbonate saturation state area from the shelf-break, slope and southern edge of the basin in 1990's and early 2000's to the central and northern basins alongside the sea-ice retreat in 2010s (Cai et al. 2010). We further observed that undersaturated, acidifying seawater is expanding both to more northern latitudes and to deeper depths (Qi et al. 2017). If this trend is confirmed by further observations, the upper 250 m of water in the western Arctic Ocean is likely to be entirely undersaturated with respect to aragonite minerals within just a few decades.

I am fortunate to have worked with caring advisors when I started (Cai et al. 1995; Cai and Sayles 1996), and to have continued to work with many creative colleagues and students and interacted with an outstanding community of scientists (Zhao and Cai 1997; Wang and Cai 2004; Jiang et al. 2008; Lohrenz et al. 2008; Xue et al. 2013; Chen et al. 2015; Huang et al. 2015; Joesoef et al. 2015; Tian et al. 2015; Cai et al. 2016). In addition to conducting research, teaching and training students, I am proud to have facilitated successful collaborations between the U.S. and China on carbon cycle research (Dai et al. 2009; Zhang et al. 2014; Qi et al. 2017; Wang et al. 2017a). My hope is that these collaborations have helped the international community in our goal of combating climate change issues together with China by making China a more confident partner in working with the world. Additionally, I look forward to seeing my current and former students and young collaborators do well in their journeys in the ever changing and challenging field of carbon cycle research.

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# A Fellow Speaks: From science needs to satellite concept. A look back and Lessons learned

Yann H. Kerr, Centre d'Etudes Spatiales de la Biosphère

I feel enormously honoured and am very thankful to be made a Fellow of the AGU. I wish to thank my nominators and supporters for putting my name forward. However, I wish to state that this honour should not be attributed to me singly, but rather to all the people I have worked with and without whom I would never have been made a Fellow. They are all part of it and deserve it as much as myself. I am indebted to the scores of PhD students and postdocs that I have supervised or with whom I did research around the globe. I believe that students and postdocs are probably one of the most gratifying part of the job for their eagerness unselfishness to do research. I was very lucky to have the opportunity to start my career with great scientists who mentored and taught me everything. And I was even more lucky to work with several scientists in a very synergistic way with immense pleasure all through the years.

To make a long story short, I have been very lucky for all these collaboration as well as for having such a tremendous team working with me.

I started to work in hydrology and remote sensing when I joined the French Space Agency (Centre National d'Etudes Spatiales – CNES), where I had the tremendous opportunity to be contacted by Dr Bernard Seguin from INRA (Institut National de Recherche Agronomique) who was a pioneer with USDA (US Deprtment of Agriculture) colleagues in Evapotranspiration (ET) estimates from space [Seguin et al., 1989]. Very soon, two other colleagues from INRA (Dr Jean Pierre Lagouarde) and from CIRAD (Centre de coopération Internationale en recherche Agronomique pour le Développement) (Dr Jacques Imbernon) joined us [Kerr et al., 1987]. We worked mainly over Western Africa and that is when I realised that as long as no real soil moisture estimates were made we would never be able to address some key science questions related to hydrology and maybe - more important to me - help towards a better management of water and thus ensure better food security.

This quest for soil moisture estimate became quite frantic. We looked very briefly at shortwave, spent time with thermal infra-red and then shortwave infrared but all had serious drawbacks when they showed enough sensitivity. The most promising was certainly thermal infra-red but it was far from enough. Microwaves seemed a good bet, but from previous work I knew sensitivity might be a problem. To account for that with Dr S. Moran at USDA we looked at change detection which can be useful for some applications but is not the actual measurements [Moran et al., 2002]. The great opportunity came with the European Remote Sensing satellite ERS-1 carrying a scatterometer the SCAT instrument. I managed to convince ESA to release the Sigma0 triplets over land so that we could work with it (it was not intended at the beginning, the instrument being made to deliver wind speed over oceans). However, after many trials we realised that it could only be used in change detection mode, our dreams in the use of angular information did not materialise, it was another proxy for soil moisture no more, no less [Magagi and Kerr, 1997].

In parallel I was investigating the potentials of passive microwaves with two other memorable mentors: Dr TJ Schmugge from USDA and Dr EG Njoku from JPL, [Kerr and Njoku, 1990].

At about the same time I was very lucky twice: my Earth Observing System (EOS) interdisciplinary proposal was selected by NASA and I was asked whether I would agree to see another proposal led by Prof S. Sorooshian from University of Arizona merged with ours. It was a tremendous opportunity I could not (and did not) miss [Goodrich et al., 1991]. It is also at this period that I met and worked with Dr Piers Sellers (SiB and Hapex Sahel) who was yet another great mentor [Sellers et al., 1996], now dearly missed.

With now these very strong collaborations in hydrology with UoA and USDA coupled with our expertise in Remote sensing we could progress even more.

But the Soil moisture retrieval issue was still pending.

Based upon the work around the ESTAR project in the US [Le Vine et al., 2001], with J-M. Goutoule (Matra Marconi Systems as it was then known) and A. Lannes (Laboratoire d'Astrophysique de Toulouse-Tarbes) we developed the interferometric 2D concept back in 1988-89 which soon became MIRAS and eventually evolve into SMOS [Kerr, 1998; Kerr et al., 2001; Kerr et al., 2010]. The latter kept me busy for a few years and still does. At first consolidating the concept and then spending many years trying to convince decision makers to sponsor it, until it was finally selected by CNES and then ESA in 1999. It was exhilarating to work with the dedicated project team led by Dr A. Hahne on one side with the science team on the other side. I cannot name all the key colleagues for the science part, there are too many of them, but the emulation, daily satisfactions and pleasures were tremendous. I cannot name them all but would like to mention Dr J.-P. Wigneron from INRA who has been working with me almost since the onset and Dr P. Waldteufel (from the Service d'Aéronomie who was instrumental in the SMOS proposal making and during all the phases of the mission, as well as Dr J. Font (ICM-CSIC), the SMOS Expert Support Laboratories and the CESBIO SMOS team.

So what are the main features and 5c worth of carry on messages I could make today for the coming generation? The main one is that you only achieve thanks to the other. Alone, in most cases, you are not much worth. As achievements are more and more based on multidisciplinary work, a good team is essential. The second one is probably that you must never throw in the towel if you have a good idea/concept. Both decision makers and colleagues tend to be conservative when new idea floats around it appears, and it takes some time to convince people believe me (after SMOS launch there were still scientist very surprised to see measurements as they believed that SMOS could never work –based on their understanding of physics!).

My vision of the future is also somewhat pessimistic if we keep on the current trend. The first issue is with research itself. Public funds are reduced by the day and hence to survive many have to initialise start-ups and small companies. The issue is that to keep their activities commercially viable they have to do two "unscientific" things: i) hide their approach so that nobody can reproduce them and become competitors; ii) have to claim permanently that they have the best product and hence somewhat twist reality or express partial statements to remain lead. For the others in the more public sector, the problem is actually similar. To have funding you have to get your proposals through and thus be unique and 'the best". As a consequence, and as same causes produce the same effects, not everything is done or presented fairly in the public sector neither.

The challenges for the coming generation is to understand these factors and try to return to a state of efficient transparency and honesty when dealing with science results. Our environment is at risk while we are the only community in a position to demonstrate it and help find ways to correct it for future generation. To be credible, we have to stop bickering amongst ourselves, be perfectly honest and fair to present the most credible conclusions to the decision makers.

But I do not want to seem pessimistic. To identify issues is solving half of them and I am very confident that our community is understanding the challenges we face and solutions or mitigations are on the way.

But we still have many science questions to address so let's get back to work as a team, so as to keep on pushing further the frontiers of science and contribute - as a community - to a better world for future generation, fighting the threats lurking in front of us all.

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# A Fellow Speaks: A note to early career scientists

Upmanu Lall, Columbia University

I was asked to address this note, in part, to early career scientists, who may be looking for direction as to how to have a successful career. Look away, look away, my young friends. Follow not my path if you seek the golden road to the echelons of academic stardom. Today, mentors and mentoring processes for young faculty and for graduate students abound. Resources are available to frame "broader impacts" for proposals, and how to be strategic in negotiations to get start-up packages, labs and reduced teaching. Advice is offered as to how to line up and compete for professional awards, network within the profession, boost one's recognition metrics and so forth. I pity the fool, like me, who chose this profession primarily out of a sense of wonder and respect for those who taught me. A question from a recruiter, when I was exploring jobs during my MS, sealed the fate. I said I might do a PhD and consider being a Professor. He said, why would you do that, do you always want to be a student? That did it. Wondrous world. A lifetime of learning and they may pay you something to do it! For many of you today, this may still be the exciting aspect of academia, and worth a wager.

I had no "mentors", quite different from what happens today. I attended conferences to learn about what others were doing; enjoyed teaching a wide range of classes – each an opportunity to learn things from a different slant; did not worry about tenure; got attracted to diverse topics ranging from non-parametric statistics to nonlinear dynamics to climate dynamics, to ecology, sustainability and economics, hazards, risk, energy, transportation, novel materials and yes, hydrology and water resources management. Sometimes I published the work, but primarily as a survival mechanism, and to help move my students into the job market. My apologies to those of them whose excellent papers never got out due to my inattention. I did not actively network within the profession or try to foist my ideas on to the mainstream. My learning was primarily private and an amazing amount of fun. I can think of others who also have very eclectic interests, and like me dabble in poetry and the arts, but are not yet getting awards. It is quite a surprise to get awards and be named a fellow of the AGU. The only way to understand it is that in my peregrinations, I ran into a number of amazing students and collaborators who took the fragments of the ideas that I toyed with, and developed distinct themes and narratives well beyond anything I may have suggested. Clearly, it is these individuals who are being recognized, since apparently I have to be elevated in the pecking order before their seminal contributions can be recognized. I salute them.

From my PhD advisor, Roy Beard, who had "just" a BS from Caltech, I learned that breadth and depth of critical thinking, and the ability to engage on any topic of interest are not at all only someone with a PhD is privy to. Curiosity, a solid foundation in fundamentals, and perseverance, are all that one needs. He was in his 80s when I discussed the dynamics of the El Nino Southern Oscillation with him, and he was able to engage in a much more technical discussion of the mathematics and dynamics of the phenomena than many hydrologists. This and other conversations on topics ranging from Probability to Quantum Mechanics to Engineering matters were some of the richest I have had with any of the renowned academics in many fields.

Sid Yakowitz, was another important influence early on. I met him at AGU, where both of us gave talks on nonparametric flood frequency estimation in the same session. I thought I had invented a method, and Sid pointed out that it was in the class of nonparametric function estimation and well known. Over the years, Sid educated me on mathematics, probability and statistics, by sending me progressively more challenging materials to read, and despite my progress always telling me bluntly that I knew nothing. Every message provided a new learning challenge. This was machine learning in the 1980s. The point is that a foundation of this sort allows one to develop a systems view across many lines of inquiry and critically think of "models" and their application. Together with a regular dose of humble pie, this may be what a mentor can and should provide.

Each new student, each new colleague to talk to represents an exciting new opportunity. What next? With some, it is worth embarking on a journey entirely new; with others it is the next increment in an unfinished story. So, what are some interesting things to consider for the 21st century? Does the future lie in an application of deep learning to the shallow water equations? Is the development of a process based model that unifies the ocean, atmosphere, surface flow, ecosystems, human systems, groundwater and nutrient dynamics at multiple scales with data assimilation from a zillion sensors the sine qua non of achievement? Facetious statements? Yes! But, these notions are not far from what many consider "science" today.

We are in the Anthropocene, as duly noted by many. As humans "dominate" nature, societal challenges of sustainability, resilience and environmental collapse start dominating the discourse. The many advances in the geosciences still leave us with a limited or uncertain understanding of the natural world, especially for prediction. How should one predict or understand a world that changes rapidly under human influence? Are human influence and its impacts predictable?

The IPCC makes a valiant, multi-scale, trans-disciplinary effort at an aspect of this question. The goal is to guide humanity away from a global environmental catastrophe, that may precipitate widespread famine, floods, forced migration and conflict. The general point has been clear for almost 3 decades, and yet the details of what one can project into the future or even a year out, remain murky. Society demands guidance for action, and as scientists we oblige. Recently, a colleague mentioned that he was working with the MTA in New York City to develop solutions for the subway system, where they had identified 3600 openings or leaks where water could come in if a hurricane struck NYC coupled with the sea level rise. A projected surge of 19ft over current water levels by 2100 would be the design criteria. NYC is "progressive" on climate change and will implement a solution to this and similar problems that are brought up. Reports as to subway failure or delays due to maintenance and other issues are routine today. My question was, "will there be a subway in the year 2100?" Autonomous electric vehicles may revolutionize public transportation in the next decade. Reinforcing aspects of a failing 150-year-old mode of transportation at high expense may be moot. We are driven by single issues and themes in daily life and in research. The wonderful advances in communication, can bring ideas to consensus and scale very rapidly, sometimes without a larger examination of the question. It would behoove the academic to take a broader view of the problems we face, consider the risks and options society faces, and initiate a richer discourse than how the 100-year flood may change in the future or should be estimated, or protected from.

Such a rapidly changing world, with omnipresent observing systems, and ways to process and communicate information, presents an exciting opportunity for the scientific community. Social media provides a window into the lives and minds of humans. Beyond the obvious dangers of demagoguery and populism, it provides a massive amount of data. In conjunction with sensors in the physical world, we have an unprecedented opportunity to learn how human activity and preferences are evolving and how these may shape the world, as well as how the environment is affecting these choices and life itself is changing on earth. As society seeks solutions for food, water and energy security for a projected 9 billion people, a feverish pace of innovation and adoption of technology emerges, and yet the real danger is that the majority of the people, who are economically disadvantaged will be left behind.

America first. A land of opportunity, but also a land where these issues are manifest today. It is a land of aging dams and levees with no national strategy to remedy the situation. A land where 2 million have no access to running water and the state of drinking water safety is unknown in many communities. Intensive agriculture contributes to groundwater depletion and water pollution. Consumer preferences vary geographically in the country, but healthier diets are changing demands for what is grown, where and how. Unprecedented low costs for solar and wind energy are leading to a rapid growth in the installed capacity of these technologies.

Pervasive global access to low cost energy will change the landscape physically and metaphorically, but how exactly? What does it mean for water systems, for agriculture, for mineral extraction, for urbanscapes and social structure? How will these systems react to floods and other climate hazards? How will they change our ability to weather droughts and impact water pollution?

A biological revolution is also afoot. Synthetic meats, salinity tolerant crops, designer nutrition from agriculture, are just a few examples that will change how we think about planetary sustainability, as all these factors collectively shape ecosystems, water, urban and climate transitions. As hydrologists, we have become used to thinking of climate as a driver of our systems, and are at the cusp of starting to look at humans, their preferences, choices, and actions as a dynamic source of planetary modification at every scale.

It is time to write "2100, An Earth Odyssey". It is all about your imagination, and the story that is fighting to emerge. The war for peace. Let's imagine it. Let's make it happen. Earth, first.

# Amir Aghakouchak: 2017 Early Career Award

The Hydrologic Sciences Early Career Award recognizes outstanding contributions to the Science of Hydrology, education, or societal impacts by a scientist at his or her early career stage. This prestigious award acknowledges early career prominence and promise of continued contributions to hydrologic science.

I am truly honored and humbled to have been selected as the recipient of the 2017 Hydrologic Sciences Early Career Award. My sincere thanks to the colleagues who nominated me for this award. I have been incredibly lucky to have worked with great mentors, exceptional colleagues and brilliant students. I owe this recognition to my collaborators, students, postdocs, and visiting scholars, and I wholeheartedly appreciate their hard work and dedication.

In this article, I would like to draw your attention to the notion of compound hydrologic extremes and the existing research gaps in this area. In the past 25 years, five billion people have been affected by hydrologic extremes resulting in over $1 trillion in recorded economic losses globally (Stromberg, 2007). A large body of literature has focused on extreme value analysis, risk assessment and impact analysis. Typically, extreme events are evaluated based on one indicator variable in a univariate framework (e.g., drought based on deficit in precipitation, extreme temperature based on high quantiles of temperature data, and floods based on annual maxima or peak over threshold) – e.g., Cheng et al., 2014. However, many extreme events (e.g., 2017 Harvey and Irma Hurricanes, 2012-2016 California Drought) are known to be compound events with multiple drivers (Moftakhari et al., 2017a; Mehran et al., 2017; AghaKouchak et al., 2014). Compound events involve multi-casual and interdependent processes, and current risk assessment frameworks are not suitable for describing their risk and recurrence intervals (Wahl al., 2017).

Let's consider flooding in coastal areas: Coastal regions are exposed to multiple flood drivers such as coastal water level, river discharge, and precipitation (Leonard et al., 2014). Dependence among the flood drivers (e.g., coastal surge/tide, sea level rise and river flow) can lead to compound events in which the simultaneous or sequential occurrence of extreme or non-extreme events may lead to an extreme event or impact (Wahl et al., 2015; Moftakhari et al., 2017a). For example, in estuarine systems the interplay between coastal water level and freshwater inflow determines the surface water level (and hence the flood probability) at subtidal and tidal frequencies (Buschman et al., 2009).

In the United States, flood hazard assessment practices are typically based on univariate methods. For example, procedures for rivers often treat oceanic contributions (e.g., tides and storm surges) using static base flood levels (e.g., FEMA, 2015), and do not consider the dynamic effects of coastal water level (e.g., USGS, 1981). Similarly, flood hazard procedures for coastal water levels (e.g., NOAA, 2013) do not account for terrestrial factors such as river discharge or direct precipitation into urban areas. Our previous studies indicate that univariate extreme value analysis may not correctly estimate the probability of a given hydrologic compound event (Moftakhari et al., 2017a; AghaKouchak et al., 2014). This points to the potential importance of multivariate analysis of extreme events in coastal/estuarine systems and consideration of compounding effects between flood drivers. Bivariate extreme event analysis has been explored in a coastal context (Salvadori et al., 2016), only from statistical viewpoint and without considering physical interactions between the flood drivers.

Here, I briefly discuss a methodological framework outlined by Moftakhari et al. (2017a) designed for multi-hazard assessment of extreme events and capturing the compounding effects of sea level rise and terrestrial flooding in coastal communities. This approach integrates the notion of failure probability to achieve a practical tool for assessing future hazards. Figure 1, conceptually describes the proposed multivariate frequency analysis approach. This hypothetical example plots the annual peak fluvial flow to a given coastal system versus its associated coastal water level (black circles in Figure 1). For a given design return period r, using common univariate frequency analysis approaches one may find a specific threshold for fluvial flow (i.e. $x^*$, shown as a dashed green line) above which events are considered to be hazardous (i.e. have return periods greater than *r*, say, 50-year event) and below which events are assumed to be safe. So, following the results of univariate frequency analysis, only the compound events lying in regions *B* and *C* with fluvial flow greater than *x** are ought to be hazardous and events with fluvial flow less than x* (i.e. points in shaded region *A*) are assumed to be safe. Using the same approach one may analyze the observed coastal water level and end up with the threshold *y** (shown as blue dashed line) above which event are considered as hazardous and below that (i.e. events lying in region *C*) are safe. Thus, following univariate approach, we may not appropriately characterize the risk. The points located in regions *A* and *C* are hazardous from one point of view and safe from another point of view. In these situations, for appropriate characterization of hazard we need to use multivariate probability analysis-based approaches that take the correlation structure between variables into account and robustly characterize the risk of compound events. In the bivariate approach, given a critical pair (*x**,*y**) shown as a red circle in hypothetical illustration, the corresponding bivariate hazard can be well characterized by the notion of "OR hazard scenario", defined as the set of occurrences such that either fluvial flow is greater than *x** or coastal water level is greater than *y**, or both (Salvador et al., 2016). The choice of a bivariate OR approach is consistent with the nature of coastal flooding, since it is sufficient that either the fluvial discharge, or the coastal WL, or both be large to produce a potentially hazardous occurrence. Thus, all the occurrences in the regions *A*, *B*, and *C* would be hazardous according to the (bivariate) OR criterion.

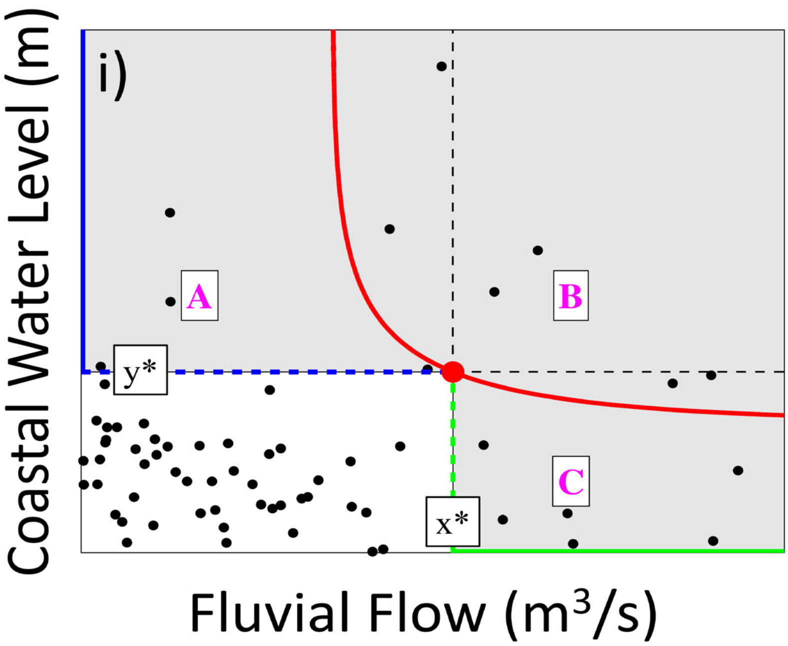


**Figure 1**. Illustration of the univariate and bivariate Hazard Scenarios. The black circles represent observed bivariate occurrences, the red circle is the reference occurrence z*=(x*,y*), the red line is the isoline of $F_{XY}$ crossing z*, with level $F_{XY}$ (x*,y* )≤min{$F_X$(x*),$F_Y$ (y*)}, and the black line is the isoline of $F_{XY}$ crossing z*, under the simplifying assumption of independence between Fluvial Flow and Coastal WL. The hazardous regions A, B, and C are indicated as dashed areas (Modified after Moftakhari et al., 2017a, PNAS).

In Moftakhari et al., 2017a, we used Copula functions to describe the correlation structure between hazard drivers (e.g. fluvial flow and coastal water level). Copulas have advantages like it is possible to account separately for the marginal and the joint behavior of the variables of interest, and marginal distributions can be of any type which make them robustly applicable to any kind of multivariate hazard scenarios. Here is an example of compound flooding in Washington, DC showing how taking difference approaches (univariate vs bivariate frequency analysis) and assumptions (dependent vs independent variables) might affect the estimation of return period for a given compound flooding event (Figure 2). In this case, the green dashed line show river flow threshold with the estimated RP of 20 yr, and the blue dashed line is associated with coastal water level threshold having 20yr RP, both of which calculated using univariate frequency analysis approach. If we take the compounding impacts of flood rivers into account, the estimated RP for the bivariate OR occurrence (*x**,*y**), shown as a red circle, would be 16 years. This example shows how taking univariate approach may inappropriately estimate the RP of a hazardous compound event. For the sake of comparison, we have also plotted the estimated RP based on inappropriate assumption of independence between variables in black curve. In this example, bivariate frequency analysis that does not address the dependence structure between variables underestimates the RP estimated using bivariate OR scenario. Therefore, neglecting the compounding effects of hazard drivers may result in an underestimation of the hazard when the combined action of multiple drivers plays a significant role.

The interesting feature of this multivariate OR hazard scenario analysis approach is that it can be linked to the notion of failure probability, widely used for infrastructure risk and reliability analysis. While this approach provides a way forward for analyzing compound extremes, there are still major research gaps. Still, we do not have a generalized framework that can be applied to different types of compound hydrologic extremes. We need methodological frameworks the can be used not only for analyzing extreme events, but also a combination of non-extreme events. Many of the existing risk assessment methods cannot be applied to samples involving non-extreme events. Yet, recurrence or co-occurrence of some non-extreme events can lead to extreme impacts (Moftakhari et al, 2017b). Finally, incorporating such methods in design and risk assessment guidelines require substantial investment over a long period of time and collaborative efforts by climates scientists, engineers, policy makers, and decision makers. I anticipate that in future more research will be dedicated to develop more physically-based frameworks for analyzing compound extremes.

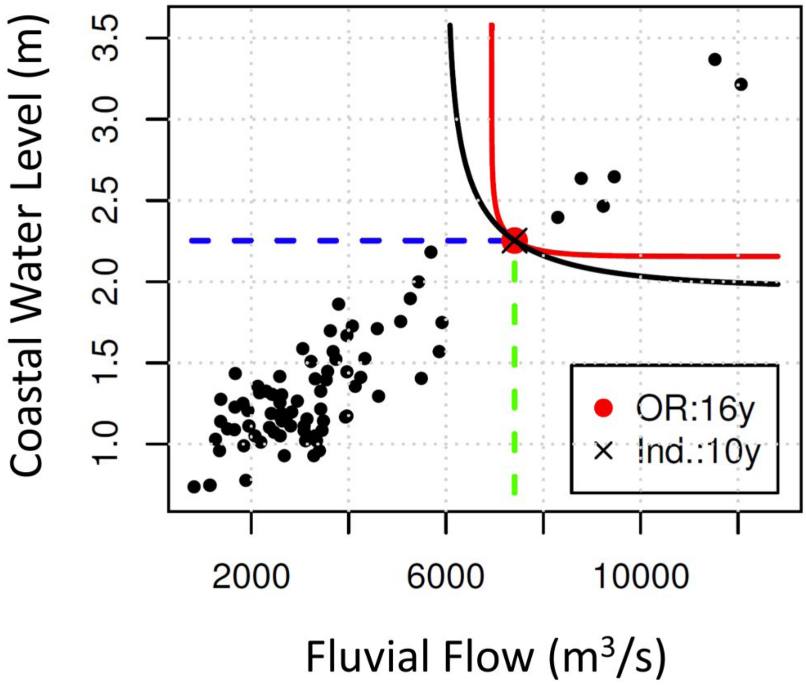


**Figure 2**. The estimates of the bivariate OR return periods (RP's) against univariate frequency estimates. The RP's associated with the occurrence z* are indicated in the legends for Washington, DC.

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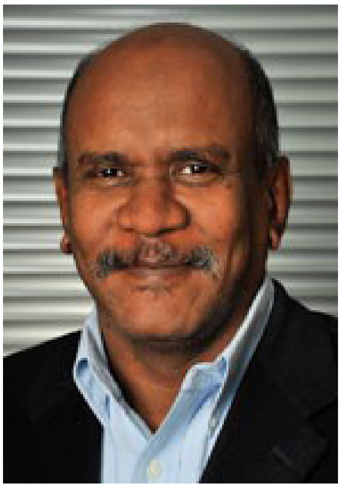
# Elfatih Eltahir: 2017 Hydrologic Science Award

The Hydrologic Sciences Award, known as the Robert E. Horton Award from 1956 to 1998, was established in 1956 and is granted by the Section for outstanding contributions to the Science of Hydrology over a career, with an emphasis on the past five years.

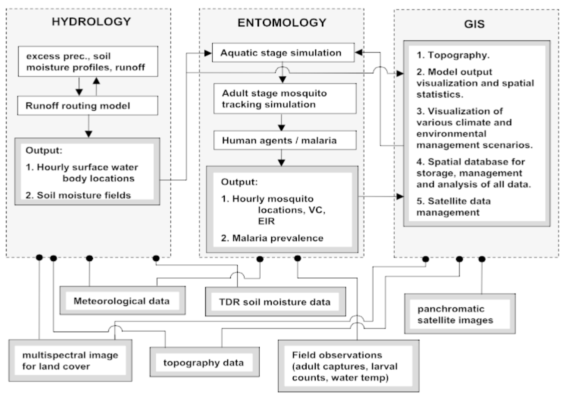


When I was taught my first lecture in Hydrology in the late 1980s, I was introduced to Hydrology as a discipline rooted in two problems: flood forecasting, and design of dams and reservoirs. As a result, I had classes on "Deterministic Hydrology" mainly addressing the first problem, and "Stochastic Hydrology" mainly dealing with the principles relevant to the second problem. In those days, Hydrology had a strong "Engineering" flavor. In the 1990's Pete Eagleson led a broad effort that attempted to redefine Hydrology as a Geophysical Science, just like other Earth, and Atmospheric Sciences. This effort had a significant but limited success in strengthening the "Scientific" foundations of Hydrology. It led to the emergence of "Hydro-climatology", "Eco-hydrology", and "Hydro-epidemiology", with significant impacts on the careers of many hydrologists including myself. However, more than two decades later, Hydrology (the largest section of the American Geophysical Union, a scientific organization) is still studied mostly within Engineering Schools in the US, and many more hydrologists are invited to join National Academy of Engineering, in comparison to the National Academy of Science.

The research in my group at MIT was influenced by the history of our discipline, but we take a step further and embrace the hybrid nature of Hydrology by adopting an approach deeply grounded in science, but motivated to solve a new class of broad and important problems related to climate change. We address two broad questions: How to inform the ongoing societal debate about climate change and its impacts, especially on water resources? and How to Engineer human adaptation to climate change, given that "stationarity" is dead, and some level of adaptation is unavoidable? Given their history and roots in problem-solving approaches, hydrologists are better equipped to address such questions, compared to colleagues with backgrounds in other areas of science.

In my group, we are interested in improving understanding of how global climate change as well as regional land use/land cover change may impact society through changes in the patterns of water availability, extreme weather, and spread of vector-borne diseases. We develop sophisticated numerical models (e.g. MIT Regional Climate Model (MRCM); and the Hydrology, Entomology and Malaria Transmission Simulator (HYDREMATS)) that are used for predicting such impacts at regional scales. We continuously improve on these models, incorporating new knowledge, and testing models' predictions against satellite observations and archived data sets of hydrologic and atmospheric variables, as well as data collected in our own field campaigns. In our research endeavors, we are always curious about how nature works, as reflected in the natural variability of the hydrologic cycle. Often, my students take a multidisciplinary approach dictated by the nature of the problems addressed. Examples for recent research from my group can be accessed at (eltahir.mit.edu/eltahir/highlighted-papers/)

For young hydrologists, at the early stage of their careers, I would invite you to confidently embrace the hybrid nature of our discipline, seek to identify a set of important problems that fascinate you, but always aspire to invent solutions that are grounded in solid scientific understanding of natural phenomena. I believe, this recipe worked for me, and I am confident that it would work for you too.




**Schematic Diagram:** Hydrology, Entomology, and Malaria Transmission Simulator (HYDREMATS)

# Robert M. Hirsch: 2017 Langbein Lecture

The Walter B. Langbein Lecture is given for lifetime contributions to the science of hydrology and/or for unselfish cooperation in hydrologic research. Additional considerations may be the candidate's renown as a lecturer and/or as an educator.

## Hydrology for a Changing World

Let me start by saying that I'm deeply honored to to be this year's Walter Langbein Lecturer at Fall Meeting of AGU. I am proud to have my name among those leading figures in the field of hydrology who have gone before me. I am particularly pleased because I have a personal connection to Walter Langbein. At the time I started my career at the USGS in Reston, Virginia, in 1976 Walter was a scientist emeritus in our office and we interacted for several years.

One of the last papers Walter published was titled: "Yearly variations in runoff and frequency of dry years for the conterminous United States, 1911-79" (Langbein & Slack, 1982). Looking at the abstract I noted two things typical of Walter. The first is this statement: "These data bring up-to-date and extend backward in time previous reports on streamflow stations by Harbeck and Langbein in 1949 which covered the period 1921-45." Walter was persistent about looking, and re-looking, at the data over large spatial and temporal scales. The abstract goes on to state: "these data show that, contained within a rather large seemingly random and sporadic pattern, there appears to be a previously unnoticed degree of similarity in the occurrence of subnormal flows across the country." This is the essence of exploratory data analysis (EDA). I share Walter's passion about searching for the signal amidst all the noise.

I have had the privilege of being a part of the USGS for more than 41. My career has three phases. First, a period of about 11 years as a research hydrologist, working on problems of water supply risk analysis, water quality trend analysis, and various statistical and economic questions related to water resources. I then moved into leadership positions in the USGS, including serving 14 years as the Chief Hydrologist of the USGS. I feel very fortunate to have been able to serve that USGS and the Nation in this capacity. It was a great opportunity for me to learn about the quality and breadth of USGS hydrologic expertise and assets. I have had the satisfaction of leading the development of programs related to water quality, streamflow, and the enhanced delivery of hydrologic data at the dawn of the Internet age.

I am now in the third phase of my career. For the last 9 years I've returned to being a research hydrologist. My main objectives have been: 1) To create and disseminate new scientific tools to help us characterize and understand the hydrologic changes that are taking place; and 2) to apply those methods to inform public decisions about issues such as water supply, water quality, and hydrologic hazards.

In the past surface water hydrologists and water resources engineers have invoked the assumption that hydrologic systems are stationary. Variables such as discharge or solute fluxes were assumed to have a mean, a variance, and other statistical properties that did not change over time. Today, the drivers of non-stationarity such as urbanization, groundwater depletion, engineered land-drainage systems, application of nutrients at the land surface, new farming technologies, and changes in greenhouse-gas forcing of the global atmosphere have perturbed hydrologic systems enough so that this assumption must be challenged. Under the leadership of my USGS colleague Chris Milly, several of us wrote a 2-page perspectives article in Science Magazine in 2008 (Milly et al., 2008). The title was: "Stationarity is Dead, Whither Water Management." Our purpose was to get people talking about this new perspective. Some of our colleagues have taken exception to our choice of words or to our basic thesis, but by any measure, we have succeeded in getting people talking. Some have concluded, wrongly, that our perspective is that past hydrologic records are now irrelevant, and we must turn to deterministic approaches to support design and operations of water resource systems. Those who take this view should note these two statements in that paper: "Modeling should be used to synthesize observations; it can never replace them." And "In a nonstationary world, continuity of observations is crucial."

Our view is that decades-long hydrologic records are highly relevant to the task of predicting future conditions. These records capture key features of the inherent variability of the hydrologic system, and this will not be going away. The records also show us how these systems have responded to changes in driving factors in the past. This knowledge is important to the prediction of how these systems will respond to new stresses in the future.

Understanding past trends in hydrologic systems is important for at least two reasons: (1) Society needs insights on the hydrologic conditions of the future as a basis for planning, operating, and regulating water resources in the future. Water resources engineers cannot depend solely on records of the past to design and operate in the future. However, simply substituting model projections for historic records, without evaluation of the ability of those models to produce realistic projections, is not acceptable. We must use the past data to test our models. (2) Searching for and objectively characterizing non-stationarity behavior, provides a framework to identify emerging water resource issues and to evaluate our society's success in achieving its environmental goals.

Over these past 9 years I've designed and published methods for evaluating trends in streamflow and trends in stream water quality. At this point, many of the tools my colleagues and I have developed are included in the R package called "Exploration and Graphics for RivEr Trends" or EGRET (Hirsch & De Cicco, 2014). It has been downloaded more than 13,000 times from CRAN and is finding its way into many hydrologic studies. At the heart of EGRET is a method of water quality data analysis called "Weighted Regressions on Time, Discharge, and Season," or WRTDS (Hirsch et al., 2010). The core concept of WRTDS is that at any location on any river we can expect the statistical properties of water quality to change in complex ways. Trends can be very different in different flow conditions or in different seasons. The method is designed to allow the analyst to see and understand the nature of the change and quantify it in ways that are crucial to effective water quality management decisions. These tools are now in use in national (Oelsner et al., 2017)and regional efforts (Sprague et al., 2011), (Zhang et al., 2016) to characterize change and evaluate the effectiveness of management practices. WRTDS takes off the mathematical "straight jacket" and lets the data speak. We have already found a number of situations where this exploratory approach has proven to be very nimble in identifying changes that simpler methods would have missed and in determining the nature of the change in ways that point towards policy solutions.

In the study of streamflow trends, the EGRET package contains some simple tools that lets us look at trends, by season, and at various points on the frequency curve (low flow versus high flow). Here again, we let the data speak. Each streamflow record has its own "trend signature" (which can include no trend at all). What can we learn by assessing these signatures all across the landscape? With my colleagues we have also experimented with new ways of looking for trends in floods and their possible linkages with greenhouse forcing see (Hirsch & Ryberg, 2012), (Archfield et al., 2016). Assessing the future of flood or drought hazard needs to be grounded in a set of diverse statistical results which are repeatedly applied as our flow records grow in length.

Hydrologic research going forward must test the suite of models in use today to predict changes in streamflow and water quality that arise from one or more of the major change-drivers such as land-cover change, groundwater depletion, or enhanced greenhouse forcing. Confidence in the models must be based on model hindcasts forced by the actual record of the change-driver variables. A key measure of the utility of these models is to see if they produce records of the past that approximate the nature and extent of the trends that have actually occurred. In my view, empiricism has too long taken a "back seat" in the body of research on these questions of hydrologic change. My goal is to continue to create and disseminate statistical tools that will help hydrologists provide a richer description of change, and to use these tools to carry out studies that are relevant to the major environmental and resource management questions that we face in the coming decades.

I believe that one of our obligations to the society that funds our work is to provide a clear set of facts about hydrologic change (or the lack of change). Those who have heard me lecture any time over the last nine years have heard me quote these words of Ralph Keeling (Keeling, 2008) (son of Charles David Keeling founder of the Mauna Loa Observatory), "The only way to figure out what is happening to our planet is to measure it, and this means tracking the changes decade after decade, and poring over the records." Walter Langbein knew the importance of all parts of this scientific process: both data collection and data analysis. We need to step up our efforts to understand the past, in order to help society better understand and manage our changing world.

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# Thorsten Wagener: 2017 Witherspoon Lecture

The Paul Witherspoon Lecture award is given in recognition of outstanding achievements by a mid-career scientist (within 10 to 20 years since PhD) in advancing the field of hydrologic sciences.

## Chance Encounters in Hydrology

I was asked to write a little piece for the Hydrology Division Newsletter in the context of having been awarded AGU's Paul Witherspoon Lecture for mid-career hydrologists. So how do you know that you are a mid-career scientist? Well, there are a few indicators. One, you get asked roughly once a month whether you want to become department head somewhere. Two, you spend more time in meetings than doing your research. And three, well I forgot number three. Maybe forgetting was the third one? But (even) more seriously, it is now 20 years since I started my PhD, and I am 20 years away from retirement age (currently 67 in the UK). So, I guess it does not get much more mid-career than this for an academic!

While I could use these paragraphs to highlight some glorious recent research, I decided to focus on something else. This is a good time to think about the people who made large impressions on me during my career. I have spoken elsewhere about my appreciation for my advisers during my studies, my PhD and postdoc years, so this will not be the focus here. Rather I would single out two chance encounters that were very important to me, likely without the people I encountered realising it. Both encounters happened during my PhD years and helped to shape my approach to research and mentoring. They also came at a time when I was not completely convinced that this academic thing was the right job for me.

I gave my first ever oral presentation at a workshop organized by the Centre for Ecology and Hydrology (CEH) in Wallingford (UK). This was maybe a year or so into my PhD and I was excited by all the things I (thought I) had learned. I had 12 minutes for my presentation, but probably included material for at least 30 minutes. So, I ran through my talk to share all these exciting and crucial new findings. When I was done, the session moderator got up and asked whether anybody had any questions. I looked at the audience for the first time since starting my talk. In my excitement, I had forgotten to do so earlier. What I encountered were a lot of puzzled faces, and complete silence. After several more encouragements by the moderator, and what felt like an eternity to me, eventually somebody raised his arm. Keith Beven asked me a question and I could tell that it was because he felt sorry for me, rather than that he was impressed by any of the 25 key points I was trying to make!

After the session, I had a long discussion with Keith about what I was trying to communicate. He invited me to visit him in Lancaster and to give a seminar at the University. And so, I found myself sitting in his living room a few months later. I found this initially quite intimidating – sitting there with the most cited hydrologist – though fortunately Keith turned out to be very easy going. We went for dinner, and talked about how one might combine hydrologic process understanding with model evaluation, which helped shape some of my ideas. The next day I gave my seminar. This time with a much better content to time ratio than in my first attempt of speaking publicly! I even noticed that a few people were laughing in the back while I was presenting my Dynia algorithm They later told me that Dynia means pumpkin in Polish. Well, Google was only about a year or two old then. Who thought about googling such things at that time!

The second chance encounter during my PhD was when I met the late Jim Dooge. I first met him when he was visiting Imperial College London for a day. He eventually was introduced to a few PhD students who were working on topics related to his work. His book on 'Linear Theory of Hydrologic Systems' had been (and still is) on my shelf from the very beginning of my PhD. I very much liked the idea of finding simple models and testing how much we can learn from their application to seemingly very complex systems. For about two hours, he gave me his undivided attention and we discussed how his research related to what I was trying to do, i.e. achieve better predictions in ungauged basins.

A few years later, I met Jim Dooge for a second time. This time I was interviewing for a Lecturer position at University College Dublin, where Jim Dooge was emeritus Professor and still spent many hours in his office. On the day of my interview he invited me for lunch in the Club he belonged to, which was located close to the Department. The Club dining room had white table cloths and the waiters were dressed in white shirts. I was not expecting such a fancy lunch an hour before my first ever job interview for a permanent academic post. He wanted to order us some red wine and was mildly irritated when I mentioned that this was maybe not a good idea in my case. Fortunately, he managed to cope well with the disappointment and we had a very nice discussion. I also got to my job interview sober.

Of course, there were other influential encounters in my hydrology career. I am very lucky to be part of a generation of many excellent hydrologists. Quite a few of them have become good friends and we have grown up together since we met during our PhD years. What I appreciated during the two chance encounters discussed above, were the famous senior hydrologists who took a debate with a PhD student (with some poorly thought out ideas) as seriously as they would have taken a debate with a well-established colleague.

"...take time to formulate a puzzle worth solving, take time to solve it thoroughly, and (equally important) take time to communicate your puzzle and its solution well."

Something else I learned from these encounters is the importance of taking time to think. I believe that one reason why papers written during the PhD and postdoc years of many academics still make it into the top cited papers much later in their career, is because then they had much more thinking time. The academics who keep writing influential research papers (I am ignoring opinion papers here) often are those who manage to protect their thinking time better than others. Keith Beven is a very good example of such an academic. Andrea Rinaldo recently told me about the many hours he and Ignacio Rodriguez-Iturbe spend debating hydrologic puzzles. They took time to think. Finding this time becomes harder the further you advance in your career. So, if I may give a bit of advice, take time to formulate a puzzle worth solving, take time to solve it thoroughly, and (equally important) take time to communicate your puzzle and its solution well.

# 2017 Horton Research Grant Awardees

Horton Research Grants are in support of research projects in hydrology and water resources by Ph.D. candidates in institutions of higher education.

## Spatial and Temporal Distribution of Ecohydrologic Separation in a Snow-Dominated Watershed

James Knighton, Cornell University
Advisor: Todd Walter

The "two water worlds hypothesis" (TWW; i.e. ecohydrologic separation) [McDonnell 2014; Evaristo et al. 2015], a reconceptualization of the classic hydrologic cycle, has recently received substantial attention from hydrologists. This hypothesis asserts that precipitation inputs above field capacity percolate freely to the saturated zone whereas water in smaller soil pores remains held tightly in the soil matrix. Available soil water then leaves the watershed via plant transpiration or soil evaporation. Competing hypothesis have emerged [e.g. Geris et al. 2015; Sprenger et al. 2016] sometimes specific to low energy catchments with reduced evaporation or highly with reduced seasonality [Tetzlaff et al. 2015]. Controlled soil column experiments have suggested that soil water mixing may occur under saturated conditions [Vargas et al. 2017] whereas with drier soils TWW dominates [Stumpp et al. 2010]. Further, recent studies have demonstrated that different plant species draw water from both groundwater and the unsaturated zone depending on soil moisture [Evaristo & McDonnell 2017a; Barbeta & Penuelas 2017].

Watersheds are generally described as heterogeneous landscapes with respect to moisture content, soil types, nutrient dynamics, and ecology [Walter et al. 2007]. We are investigating whether TWW may similarly be best described as a phenomenon that may not occur broadly across entire catchments through all seasons, but rather during specific seasons and unique locations within a watershed. TWW has primary been investigated in the context of meta-analysis of hydrologic data comparing the deuterium-excess of soil and plant water to that of precipitation and streamflow across sites [Evaristo & McDonnell 2017b] though there has been some recent debate surrounding our ability to relate isotopic enrichment to soil water mobility [e.g. McCutcheon et al. 2017]. We are approaching this problem from the context of testing TWW by examining the appropriate structure of mechanistic hydrologic models to replicate the isotopic distribution of water within a single watershed, building on our previous research [Knighton et al. In Press]. For a forested watershed in Pennsylvania, USA we demonstrated that observed seasonal soil water isotopic composition was best explained by ecohydrologic controls (i.e. plant growth) and some displacement of enriched water soil water by incoming precipitation and snowmelt.

The Horton Research Grant allows me to take this research further to collect data on ecohydrologic separation at several locations within a forested, snow-influenced catchment in central New York, USA (Figure 1) across a gradient of Topographic Wetness Indices (TWI) (Buchanan et al 2014). From January 2017 through 2018 we are performing weekly sampling of precipitation, snowpack, canopy throughfall, streamflow, and shallow soil water isotopes. During the summer of 2017 and throughout 2018 we will collect plant stem water samples from American Beach (Fagus

**Figure 1**. Skiing to Six Mile Creek in February 2017 to collect precipitation, snow, and soils

grandifolia) and Eastern Hemlock (Tsuga canadensis), the dominant woody plant species within the watershed. All soil and plant water extractions are performed with the cryogenic extraction methodology. We will apply these data to our mechanistic soil column model to infer which type of unsaturated zone mixing structure best matches the soil isotopic signature for each location and season.

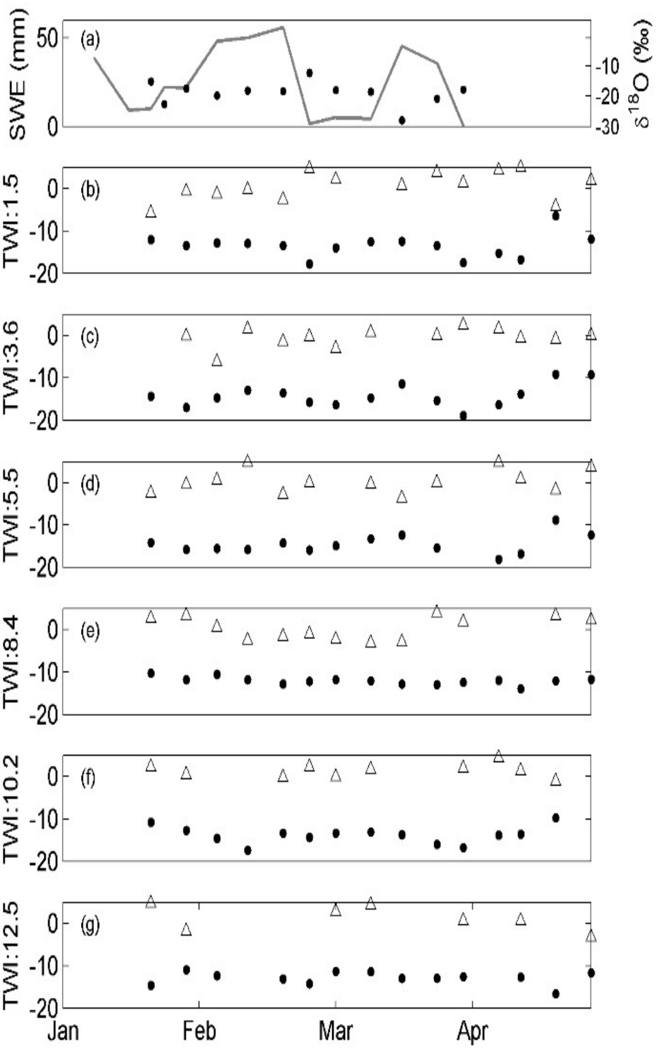


**Figure 2**. (a) Snow water equivalent (line) and snowpack $\delta^{18}O$ (dots), and( b – g) soil water $\delta^{18}O$ (dots) and line conditioned excess (triangles) across a TWI gradient

Preliminary data collected during the winter and spring of 2017 recorded two distinct periods of snowmelt where soils infiltrated isotopically depleted (i.e. lighter) melt water (Figure 2a). So far we have observed substantial differences in the response of soil water content across the TWI gradient to these periods of snowmelt (Figure 2b - g). All sampling locations demonstrate an initial drop in soil water $\delta^{18}O$ following each snowmelt. A qualitative interpretation of these data suggests that lower TWI (drier) location soil water rapidly recovered to pre-melt isotopic concentrations suggesting the depleted melt water contributed only to mobile water. In contrast wetter locations maintained the depleted signature of the snowpack suggesting some of the newly introduced melt water displaced soil water.

The next steps in this research are to continue field collections and then apply our mechanistic model to see what assumptions about water movement through the landscape are necessary to reproduce the patterns we see in our isotopic water data to our mechanistic model. We hope to determine how much observed changes in soil isotopic signatures can be attributed to soil percolate mixing within the root zone versus influence from runoff partitioning, plant water uptake, and evaporative fractionation.

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# Use of multiple tracers and geochemistry in tandem with numerical models to improve understanding of mountain-block recharge processes in a high elevation, sub-humid catchment

## Ravindra Dwivedi, University of Arizona

### Advisor: Thomas Meixner

In the Western U.S., mountain systems provide drinking water to more than 60 million people [Bales et al., 2006]. However, mountain systems are not only regionally important, they are in fact globally important locations of recharge for waters that ultimately end up in the adjacent alluvial basins, which act as an important groundwater resource for numerous arid and semi-arid regions [Viviroli et al., 2007].

Unfortunately, little is known about mountain system recharge (MSR) processes, consequently there is a large uncertainty in our current MSR estimates [Manning, 2002; Manning and Solomon, 2004; Wilson and Guan, 2004]. Therefore, the main objective of my doctoral research is to improve our understanding of MSR processes, especially mountain-block recharge processes (Figure 1). An improved understanding of MSR processes is also required for predicting probable response of MSR processes to increased aridity and reduced snowpack and snowpack duration due to climate change [Harpold et al., 2012; Meixner et al., 2015; Mote et al., 2005]. In the local and regional context, an improved understanding of MSR processes will be valuable for water sustainability in regions such as Arizona, where more than 66.5% of the total area can be characterized as mountainous (using definition from [Kohler and Marselli, 2009] and topographic data from PRISM climate model [PRISM Climate Group, 2016]).

To achieve these research goals, Dr. Meixner, Dr. Jennifer McIntosh, Dr. "Ty" Ferré, Dr. Jon Chorover, and I propose using multiple tracers such as stable water isotopes, tritium and 14C and solute chemistry for sampling flow paths responding at various space and time scales for the Marshall Gulch catchment located at the high elevations of the Santa Catalina Mountains, Tucson, Arizona. Furthermore, we are supporting the multiple tracer observations with approaches such as time-variable Transit Time modeling [Harman, 2015], which models transit time at the catchment outlet assuming a catchment-scale control volume; it thus considers whole catchment as a "black box". Subsequently, we plan to open the "black box" through simulating the groundwater age distribution. We are expecting numerical modeling of groundwater age and observations with tracers and geochemistry to contribute significantly and uniquely to the presently limited understanding of recharge processes in mountainous catchments for which observations are hard to make and site instrumentation is hard to develop due to extreme climate and topographic gradients [Bales et al., 2006; Manning and Solomon, 2005; Wilson and Guan, 2004].

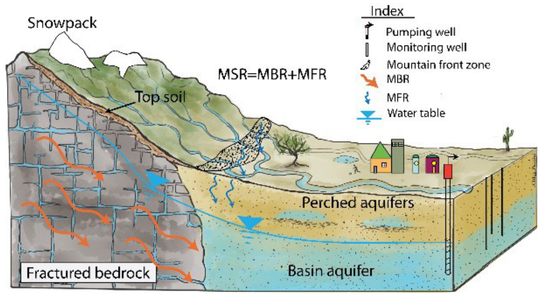


**Figure 1**. Mountain system recharge processes and the importance of such processes for water sustainability in the adjacent alluvial basins. Figure Credits: Chloe Fandel

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# Is there trouble in the tundra? Towards understanding flow in an aquifer made of carbon

Michael O'Connor, University of Texas at Austin

Advisor: M Bayani Cardenas

We had been sitting in our vehicle for about 25 minutes, staring at the hindquarters of a rather stubborn moose with little regard for traffic patterns. Few places on Earth are so truly foreign to human life than the vast expanse of stark landscape that makes up the high Arctic. The North Slope alone occupies an area larger than Utah, with a population of a small village. I impulsively checked my cell phone, for no particular reason, and was obviously greeted with a 'no service'—and a reminder that we were, very clearly, on the moose's turf.

However, within this beautiful wilderness lies nearly half the soil carbon found on Earth1. Most of it is locked up in permanently frozen soil; however, the Arctic is also expected to warm more and more rapidly than any other region on Earth. This warming threatens to thaw vast volumes of soil carbon, freeing it to be respired by microbes, dissolved into groundwater, and evade into the atmosphere as greenhouse gases2. Understanding the timing and magnitude of this potential carbon punch explains why I had spent nearly half an hour stuck in the tundra behind an apathetic and sizeable moose.

Our goal is to quantify how much greenhouse gas amplification will arise from the export of carbon-rich groundwater to surface water bodies across the North Slope of Alaska. We do this in two parts: first, by measuring hydraulic parameters and groundwater flows in the field, and second, by using those observations to inform predictive models at meter, kilometer, and basin scale. Our field observations have revealed an interplay between rapidly-decaying porosity with depth and gradually increasing aquifer saturated thickness throughout the season. This interplay is the most significant factor governing if the tundra will readily export groundwater at significant rates. Furthermore, our field observations and simulations have helped us predict which factor wins, and where it does.

The Horton Grant is instrumental in applying these findings to a predictive framework. It has funded field research that expanded our dataset of tundra hydraulic properties to a much wider scope, enabling us to make basin-scale estimates of arctic groundwater flows. Further, it has funded the implementation of the Advanced Terrestrial Simulator (ATS), one of a handful of numerical models able to simulate the transport of water and energy through variably-saturated soils, including freeze-thaw3. We now use ATS, informed with our expanded field observations, to predict the fate of groundwater flow trends as the tundra experiences decadal-scale warming, and to determine groundwater transport 'hotspots' within the tundra environment. This combined approach is leading to the development of the first basin-scale predictive arctic groundwater flow estimates—an integral puzzle piece needed to predict the future arctic carbon balance.

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# Jean Bahr: AGU Ambassador Award

The Ambassador Award is given annually to one or up to five honorees in recognition for "outstanding contributions to one or more of the following area(s): societal impact, service to the Earth and space community, scientific leadership, and promotion of talent/career pool."

I love the idea of being considered an "ambassador" for the Earth Sciences. As I look back on my career, many of the activities that have brought me the most personal satisfaction (as well as frustration) were those that involved representing the geosciences in general, and hydrogeology in particular, in questions related to public policy. I have enjoyed sharing my passion for our science, as well as my conviction of its importance to society, with audiences ranging from students in introductory to graduate level courses at the University of Wisconsin-Madison, to local civic groups, to the institutions I visited as the Geological Society of America Birdsall-Dreiss Lecturer, and to governmental decision makers through service on boards and committees of the National Research Council, on advisory committees to state agencies in Wisconsin and, most recently as a member of the US Nuclear Waste Technical Review Board. I have participated in meetings and briefings with congressional staff during the annual Geoscience Congressional Visits Days to discuss the importance to society of sustained federal funding for geoscience research and education. I have also been fortunate to have had several international ambassador opportunities. The first of these was shortly after college, when I got to spend two years sharing my (then meager) knowledge of hydrogeology with a technical team in Mali, West Africa. Most recently, I was able to represent the American Geosciences Institute and some of its member societies while presenting an invited short course in Bucaramanga, Colombia last January.

My father, an electrical engineer, encouraged my early interest in math and science. My mother, who studied economics with one of those who popularized the term "Spaceship Earth" in the 1960s, was a consistent, active model of her dedication to good will among people of many cultures and to creating a more just, healthy, and peaceful society. Together, they inspired me to find a career that would challenge me intellectually but that also had the potential to make a difference. During the first Earth Day, I saw a path that would easily combine these two. I entered college a few years later with the goal of becoming some type of environmental scientist, finding my way to a major in geology and geophysics courtesy of faculty who highlighted the fact that our planet is, after all, our environment. My graduate mentors from Stanford, Environment Canada, and the USGS provided me with outstanding hydrologic training and as well as tangible examples of how our science can be used to address environmental and societal problems. I have done my best to offer similar training and good examples to my advisees.

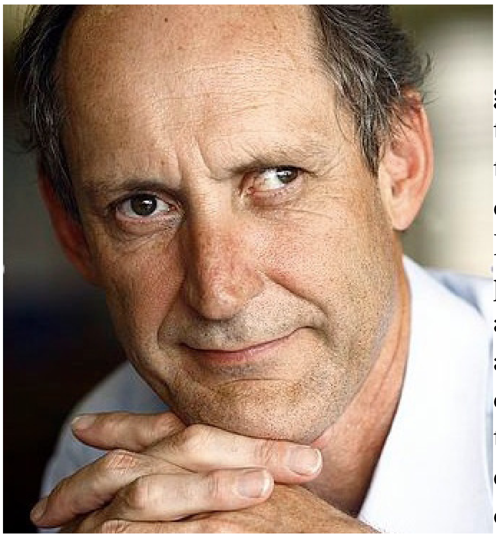
I hope that each of you, as members of AGU and of the Hydrologic Sciences Section, will consider ways in which you can strive to become an ambassador in your own right. In a time when many in society question the value and validity of science, we need to be strong and steady advocates for, and practitioners of, the scientific method of hypothesis testing based on observations and data from the natural world and from carefully designed experiments. We should all be active participants in fair and constructive peer review, which helps to build confidence in the conclusions of our work both among scientists and the public. Modeling good scientific practices in our own work and publications, and promoting respectful interactions among senior and junior colleagues, are essential steps to developing and sustaining a positive public image for our field.

Building on that positive base, we can share the excitement of hydrologic science and the importance of its results with the public in myriad ways. At the K-12 level opportunities include participating in programs such as AGI's Earth Science Week, Science Oympiad, and Expanding Your Horizons (a STEM career program for middle school girls). CUAHSI's "Let's Talk About Water" film and discussion program offers a way to engage university and community audiences around local to global water issues. You can share your expertise with elected representatives when they face issues related to water, or more generally to the Earth Sciences, in pending legislation. You can also share your expertise broadly through letters to the editor and via postings to your social media networks. And even if you do not have a lot of time for volunteer activities, you can provide financial support to organizations that have strong science education and public policy programs.

# Hubert H.G. Savenije: International Award

Established in 2007, the International Award is given annually to one honoree (individual scientist, group, or small team) in recognition "for making an outstanding contribution to furthering the Earth and space sciences and using science for the benefit of society in developing nations."

## Doing research in developing countries is rewarding!



It is really great to receive the International Award of the AGU. In my interpretation, this award has two aspects: it recognises contributions to enhanced understanding of Earth system processes, in my case hydrological processes, in regions outside the well-studied Western World, and it also recognises the benefit this research may have provided to people and societies in developing regions. I think both aspects are equally important. To start with the first, I have always found the hydrology of tropical countries far more interesting than the hydrology of temperate zones. Temperate hydrology is much less dynamic and has much smaller extremes. I think that the fact that countries in temperate regions have their water management generally in good order is not due to their advanced engineering capacities and hydrological understanding, but rather the fact that in those regions engineering interventions are easier to implement. Speaking of my own country, The Netherlands, I think it is due to the fact that our hydrological system is so gentle, predictable and sluggish that we have had the opportunity to experiment at will, and even make serious mistakes, without major environmental repercussions. In so doing we have had the opportunity to develop a water management system that is reasonably resilient and safe. But it is not that simple in tropical climates. Because of its higher dynamics, the hydrology of tropical regions is far more complex but also far more interesting than the highly predictable handbook-hydrology that I was brought up with. So already during my studies, I decided that I wanted to work in developing countries, where my efforts would hopefully be relevant.

This touches on the second aspect of the International Award: the relevance for development. In tropical regions, the average situation is seldom the norm. There are regular droughts, and often these are followed by floods. During drought years, the water related problems are so overwhelming that people can't imagine it will end with a devastating flood. During floods it is the other way around. Hardship is closely connected with water. Hunger, lack of water and sanitation, poor health, pollution, floods, energy shortage, and poverty in general, are closely linked to the state of the water system. Research aimed at better understanding the often-complex functioning of the water system can help alleviate human suffering and contribute to prosperity. So, not only is the hydrology of developing regions highly interesting, studying it is also highly relevant.

But there is a caveat. There are different ways of doing it. For some researchers, it is tempting to fly in, collect data, go home, write a paper and become famous. These are what I would call safari scientists. Fortunately, I don't know many of this kind. But I know several of a milder variety. They offer fellowships to promising young scientists from developing countries, give them a subject of study which is hardly related to their water world, separate them for several years from their home country, and -- after graduation -- either retain them, contributing to brain drain, or send them back with a doctor's degree, but with hardly any relevant knowledge on how to deal with their own more vigorous environment.

Fortunately, I am happy to know many water scientists who do it differently. There is no panacea, but there are a number of requirements to make a contribution successful. First of all, research should be demand or problem-driven. This is not so difficult, because there are problems galore. Next, there should be a local owner of the problem, who should be engaged in the research right from the start. It should also involve local students and researchers who actively take part in the process of planning, implementing and disseminating the research. Finally, it should contribute to building capacity to carry out research and its application. In general, being inclusive is the most important. If possible, carry out the research and the capacity building within a network of participating partners. Don't be afraid to share your research, your findings and your knowledge, the reward is that you will receive a multiple of what you invested.


**Photo**: Students fly a drone over an ungauged tributary of the Zambezi river, to determine a detailed digital elevation model for river rating.

Over the years, I have done research on a variety of subjects with many different students from developing regions in the fields of salinity in estuaries, hydrological modelling, atmospheric moisture recycling, and sustainable smallholder agriculture. I shall highlight a few contributions in these fields.

For estuaries, I developed a relatively simple analytical theory with which we can predict the salinity distribution and the tidal characteristics as a function of the estuary geometry (see: Savenije (2015) and www.salinityandtides.com for my on-line book on the subject). This has led to very interesting applications in about 20 estuaries spread all over the globe, which have been essential in substantiating the theoretical background of the approach. A nice application is by Ali Abdallah (2016) in the Euphrates estuary, where he did fieldwork under very difficult circumstances; or the applications by Nguyen Anh Duc (2006, 2008) who could use the salinity distribution in the Mekong to determine the discharge distribution over the delta branches; or by Erfeng Zhang (2011 and 2012) who studied both the tidal propagation and the salinity distribution in the Yangtze; and Jacqueline Gisen (2015a, 2015b) who surveyed 7 Malaysian estuaries, developed predictive equations and derived equations for estuary shape.

On hydrological modelling I developed a flexible modelling concept based on landscape characteristics (Hongkai Gao, 2016) with an application in Thailand. This approach also proved to work very nicely in the semi-arid HeiHe basin in China (Hongkai Gao, 2014a) and also in tributaries to the Upper Blue Nile (Sirak Tekleab, 2015). Within this modelling concept we showed that the root zone storage capacity could be derived from historical records (Hongkai Gao, 2014b), which Lan Wang-Erlandsson (2016) applied globally.

We also worked on closing water balances of river basins, taking into account the moisture recycling through the atmosphere. In this approach, Yasir Mohamed (2005, 2014) made the water balance of the Sudd wetlands of the Nile, and analysed the amount of moisture that is recycled within the Nile basin.

Finally, I worked with a number of students on improving smallholder agriculture. Subha Vishnudas (2012) worked on slope stabilisation with geotextiles in agricultural fields in Kerala, India; Hodson Makurira (2010, 2011) analysed the efficiency of trenches to harvest runoff and conserve soil and nutrients in Tanzania; and Melesse Temesgen (2012a, 2012b) analysed the effect of trenches and strip tillage to enhance agricultural productivity in Ethiopia.

So, I am extremely happy with this award and grateful to the people with whom I have worked for so many years in different parts of the world. Not only have they inspired me and worked with me on all these challenging hydrological questions, they also contributed in many different ways to a successful outcome, and I would certainly not have deserved this prestigious award without their energy, ingenuity, friendship and support.

# International Award...Savenije (continued)

**Photos**: Field work along Zambezi valley tributaries

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# Report of the AGU Hydrology Section Task Force on Strategic Communication

*Members of the Hydrology Section Task Force on Strategic Communications: Harsh Beria, Niels Claes, Jaivime Evaristo, Jay Famiglietti (Chair), Evan Kipnis, Hari Rajaram, Sasha Richey, Kelly Twomey Sanders*

Science communication can take many forms and serve multiple purposes. From public speaking, to media interactions, to state and federal testimony, there are several roles that professionals can play in educating the broader community. Despite the growing importance of communicating the societal relevance of hydrologic research, a wide range of attitudes towards engaging in communication activities exists in our field -- from embracing it as a professional responsibility, to ignoring it as an undesirable nuisance. Clearly, the degree to which an individual participates in communication is a personal choice that is driven by individual and professional goals.

In order to explore the issues and opportunities surrounding science communication, Hydrology Section President Jeff McDonnell assembled a Task Force on Strategic Communication (membership listed above). The goals of the Task Force were to characterize the importance of strategic communication to the Hydrology Section, and to recommend what it should and could be doing. The committee held several teleconferences over the course of the spring and summer of 2017, and committee members conducted several informal interviews with colleagues and with communication professionals. What follows is a brief report on findings from those interactions, with recommendations from the committee. The report will serve as the basis for a longer, peer-reviewed article to appear in 2018.

**Finding #1. Know your strategic communication goals and targets.**

There are many reasons to communicate broadly (i.e. beyond peer-reviewed literature). The committee agreed that each communication effort should be concise and focused on strategic goals. *What* do you want to say, to *whom* do you want to say it, and *why*? Important goals might be to raise awareness around critical water issues, or to bridge the research to operations gap, or to educate decision makers to better inform policy decisions. A typical target audience could be the general public, university administrators, professional societies, water managers or elected officials. Key messages may be as simple as your personal or group sound bite, that you have made a breakthrough in understanding or methodology, or more practically, that your work is important and needs funding.

All of these will dictate the communications vehicle. Some common examples are meetings with local water managers or stakeholders, public talks or opinion pieces, social media, press releases, media interviews, and state and federal congressional briefings.

"Since many target audiences do not read the academic literature, additional effort is required to disseminate the desired information."

Regardless of goals and targets, the committee believes that a thoughtful and strategic communication *plan* can be extremely effective in getting a particular message out. A new, important research finding may require a press release or a press conference, associated media interactions, a series of public and research lectures, state and federal briefings. If the finding is of profound public or policy relevance, an opinion piece in a local or national newspaper may be desirable. Social media messaging may be appropriate for expanding the reach of the message. Other messages may require a different approach, for example, a series of meetings and workshops with stakeholders. Since many target audiences do not read the academic literature, additional effort is required to disseminate the desired information.

**Finding #2. There are many benefits to communicating our science**

The committee characterized the benefits of enhanced science communication efforts beyond traditional, passive pathways into three broad categories. These include experience, exposure and societal benefit.

The core criteria upon which academic researchers are evaluated necessitate effective communication to publish papers, apply for grants, give oral presentations, teach and work productively with students. Therefore, the potential benefits of science communication at all career levels are extensive: any additional experience at communicating to diverse audiences can benefit these core academic tasks.

For example, early-career academics could gain experience at communicating concise and simple messages (e.g. through social media) to improve their ability to communicate in teaching settings to students with differing backgrounds and levels of interest. All academics can gain experience from communicating with journalists to improve their ability to give oral presentations at large conferences (e.g. at AGU Fall Meeting). In both of these settings, the audience may be diverse, but still interested in methodological detail with an emphasis on core findings and delivered via simplified messaging.

A common pathway to publicize new research is to write and distribute a press release. The press release must contain similar elements to those required on the first page of a large proposal, including a hook, scientific justification and merit, and potential implications of the work. Members of review panels are not always experts in the field of the proposal, so clearly articulating *why* the research is important is just as necessary as *how* it is conducted. These are both elements required when communicating to broad audiences.

Greater exposure to hydrologic research is another benefit of science communication at all career levels. As the traditional funding environment becomes increasingly competitive, it will be advantageous to find non-traditional methods to fund research, for example through private and/or philanthropic foundations and donors. Having research highlighted in mainstream and social media can provide greater visibility of hydrologic research that could lead to enhanced funding opportunities.

These pathways could also increase the visibility of research within the broader Earth science community and lead to an increase in interdisciplinary collaborations. For mid- to senior-career researchers, the visibility could lead to invitations to provide expert testimony at state and federal levels. Another societal benefit to communication is to increase the general public's awareness and understanding of scientific issues. Benefits of doing so include enhancing the information the public has access to for informing voting decisions and also increasing students' awareness of career opportunities in Science, Technology, Engineering, and Mathematics (STEM) fields.

**Finding #3. Don't feel bad if science communication is not your thing.**

Science communication is not for everyone, nor should it be. Many researchers prefer to publish their papers and move on to the next project. Others are simply uncomfortable talking to the media or to elected officials. Still others fear the real possibilities of being misquoted, of generating controversy, or of being targeted by skeptics.

The committee also recognized that there is little academic reward for the significant time that science communication can require. Moreover, communication is sometimes misinterpreted as attention seeking, and may be frowned upon by colleagues. As such, early career scientists may avoid engaging as much as they would like. Importantly, institutions that recognize the importance of engaging in communication must begin rewarding such achievement in the promotion process, and must be prepared to protect rather than punish employees when things go awry.

For those who don't want to engage directly, there are still many options if communication on a topic is still desirable. Senior co-authors, department chairs, supervisors, center directors, deans, etc. can all play a role in helping to get an important message out.

**Finding #4. The emerging importance of social media networks.**

Social media networks have introduced non-traditional platforms for communicating information, yet these networks are still utilized more by scholars for consuming information rather than disseminating their own research. However, given the growth of "fake news," "pseudoscience," and the mistrust existing between the public and science communities, there is increasing motivation for scientists to be more "public facing" in their selected communication pathways.

Social media offers democratized communication channels, the real-time creation of content, and the potential for interactive discourse; thus, major benefits of these emerging communication platforms include the ability to disseminate data, information, and ideas to a social network quickly, while enabling the back and forth discourse between those that create content and those that receive content. Accordingly, social media networks can provide scientists with a platform to engage with other scientists and stakeholders who can provide critiques, feedback, validation of ideas, and in some cases lead to meaningful collaborations, while also increasing the impact and dissemination of their work.

Barriers to social media participation by scientists can include the lack of institutional support or credit for engagement in social media platforms, the concern that social media platforms might be seen as illegitimate, as well as the perceived risks of losing credibility with senior researchers, the misinterpretation or misrepresentation of results, or intellectual content violations (e.g. copyright violations, plagiarism, etc.)

Despite these barriers, there are many reasons for scientists to adopt non-traditional forms of communication, and the potential value realized by such platforms can vary according to career stage. For example, social networks can provide students and post-docs with access to seek advice or build professional relationships with more senior scientists in the field. Similarly, they can provide early career researchers a venue to engage and build their reputation with more senior colleagues, while offering professional support networks that can offer advice and informal mentorship. Research suggests that while researcher seniority correlates to impact on dedicated academic social media platforms (e.g. ResearchGate and Mendeley) and more generic platforms (e.g. Twitter and Facebook), the correlation is weaker for the latter category since junior scientists are generally more open than senior scientists to these platforms. Given the potential benefits, formal training and support for these activities could facilitate broader engagement to build trust and comfort in using these services.

Despite the challenges of participating in and developing frameworks to quantify the societal impact of communicating research across diverse and evolving non-traditional communication outlets, the potential benefits of such prospects are large. Non-traditional research communication networks can support research dissemination in formats that are faster and accessible to broader and more diverse populations, as compared to traditional publications blocked by paywalls.

**Finding #5. There is a growing interest among early career scientists in science communication.**

Young scientists acknowledge the importance of being good communicators, but often think that this is a talent you are born with. This misconception can be dealt with at an early career stage, since communication skills can be learned and mastered over time. Most institutions provide courses or workshops in scientific communication within the research community and beyond, towards the broader community. Additionally, professional societies provide workshops and training as well -- for example, through the AGU "Sharing Science" program or the American Association for the Advancement of Science (AAAS) Center for Public Engagement with Science & Technology. Several private companies also provide communication training and organize hands-on workshops.

The AGU program is designed to help scientists effectively share their work with broader audiences. Tools and advice include different communication channels, social media advice, and audience-specific advice. Examples here are tips and tricks on how to engage via different social media platforms, or tools that are useful when planning talks for different types of audiences.

The AAAS program offers workshops and communication toolkits that focus on how to effectively communicate scientific information. Examples of these are the "Working with Journalists," or "In-Person Engagement" toolkits with advice and examples about effective communication in both settings.

Attending all these workshops and courses, however, is not enough to turn young scholars into good communicators. Communicating in front of large audiences, speaking up during a scientific debate, or giving live interviews on radio or TV requires courage, confidence and practice. Mentors can help build this confidence by providing regular opportunities for communication practice within their research groups and their other professional activities.

As discussed above, young scientists (as well as mid-career and senior scientists) run the real risk of being misquoted, of having quotes taken out of context and of generating controversy. The lack of a reward system for public engagement is a further disincentive to young scientists to communicate. The committee agrees on the need for improved communication and the need for better science and evidence-based decision-making. However, in order to encourage and stimulate early career scientists to elevate their communication skills and engage more effectively with society, the reward system will need to reflect contributions made towards science communication. In addition, the committee finds it beneficial to foster a working relationship with the on-campus media lead or local reporter. By establishing such a relationship, there are more opportunities to discuss one's research openly so the reporter better understands it and runs a lower risk of misrepresenting research findings.

"The lack of a reward system for public engagement is a further disincentive to young scientists to communicate."

**Finding #6. Alternative metrics can help evaluate the contributions of science communication.**

Since this committee report largely highlights the benefits of enhanced science communication, and suggests that it should be considered positively in tenure and promotion decisions, methods for evaluating the impact or contributions of communications efforts could be as valuable, for example, as the widely-utilized h-index. The committee recognizes, e.g., the value of science-informed decision making, but it also recognizes the extreme difficulty in tracking whether a body of research and associated communication can be directly linked to a new policy position or decision. Alternative metrics, described below, may ultimately play an important role in helping to evaluate communication efforts.

Conventional metrics designed to measure research quality and impact typically include basic indicators such as number of publications and the number of citations to those publications, and more sophisticated indicators such as Journal Impact Factor, h-index, and field normalized citation indicators. The transition towards internet-based and networked research products has created an environment ripe for innovation as it relates to alternative metrics for assessing scholarly impact. Consequently, "altmetrics" have developed as means to quantify the broader societal impacts of research that might not be adequately captured by traditional bibliometric indicators, which are often limited to assessing peer-reviewed journal articles.

Several commercial altmetrics indicator aggregators exist (e.g., Altmetric.com, PLUMx and ImpactStory) and each quantifies impact slightly differently. Similarly, most major publishers now report a number of usage metrics to track a product's impact beyond formal citations alone.

Despite these efforts, there is still not a strong relationship between altmetrics (e.g. social media followers, number of views, and downloaded content) and more traditional bibliometric indicators. Given the number and diversity of platforms through which research can be disseminated and the diversity with which users can interact within those platforms, creating meaningful and long-lasting altmetrics is not straightforward. There is also a fear that altmetrics might drive perverse incentives to generate content of poor scientific quality.

As such, developing well-accepted metrics to quantify and compare the impact of more informal communication platforms, such as Twitter, blogs, Mendeley, etc., is still a very active and growing field of research. However, these metrics do not yet play a strong role in defining a scholar's impact or case for promotion.

**Finding #7. You are not alone. Significant help is available on and off campus.**

Beyond the training mentioned here, for example, by home institutions, professional societies and by professional communication trainers, several other important resources exist at most universities and research laboratories. Most institutions have media relations offices with staff that will directly assist with communications training. Most have state and federal relations staff that will help coordinate and assist with preparations for legislative and congressional meetings, briefings and testimony. Similarly, most universities have dedicated development staff that will guide researchers through the process of presenting their research to potential donors or foundations in ways that will resonate most effectively with the particular sponsor. The committee expects that these resources are generally underutilized by the hydrologic community, and it urges individuals to take full advantage of such local support if it fits within a strategic communication plan.

**Recommendations for the Section**

• The Section should consider how to best represent and foster Strategic Communications at the highest level of Section leadership For example, should a set of tasks be assigned to an individual? To the incoming or outgoing president? Should there be a standing subcommittee?

• The Section should coordinate and assess existing communications capabilities, use of social media platforms, training, etc., within AGU, Water Resources Research, and the Section itself. Existing resources should be listed on the Hydrology Section website.

• If such training does not yet exist, the Section should develop or coordinate training for Early Career Scientists that includes graduate students, postdocs and young faculty.

• The Section should establish a Hydrologic Science Communication Award (or Medal or Prize) in order to elevate its stature and recognize achievement.

• The Section should consider the role of video abstracts for selected meetings, sessions or perhaps special sections of journals.

• The Section should form a committee on 'rewarding science communication in the promotion and tenure process' to provide recommendations that research institutions can begin to consider. As part of these recommendations, the Section should follow the development of quantitative altmetrics and other new metrics for assessing the impact of communications endeavors.

• The Section should explore developing a communications mentoring program, where senior Section members can work directly with one or more young communicators. This could be part of a broader 'young leaders' program like that of the AAAS.

• The Section should encourage young members to engage in scientific communication by providing a platform during the yearly Fall Meeting as well as online that gives young scientists the opportunity to practice their communication skills and get constructive feedback by their fellow community members.

• The Section should hold one or more workshops on how to develop a communications plan.

• The Section should organize a series of AGU sessions/panels/town halls on Strategic Communications in Hydrology. Sessions could include 'lightning round' talks that emphasize effective and concise messaging.

• The Section should encourage its interested, senior membership to integrate communications training activities into the fabric of their research and training programs.

• The Section should encourage those interested members in being listed as AGU topical experts and as topical experts in their home institutions.

• The Section should consider how CUAHSI can be engaged in all of the above, including organizing workshops, engaging students and young faculty, etc.

***Within the Section***

• The committee recommends that better internal communication, from leadership, through technical committees, to membership including students, be sought through the use, e.g. of social media groups, for enhanced communication on sessions, highlights, breakthroughs, etc.

• The committee recommends that the Section pursue enhanced internal communication amongst its journals and authors, notably between WRR, GRL and Hydrology and related membership. This could be accomplished by an Annual Town Hall, or via judicious use of the Newsletter, or by the social media groups mentioned above.

# When Uncertainty Matters

Saman Razavi (University of Saskatchewan;
Deputy Chair of AGU Technical Committee on Hydrologic Uncertainty)

Hydrologic models are widely employed for the simulation of complex physical processes that comprise the Earth's water systems. They have become essential tools for management and decision making under uncertainty and non-stationarity, by providing the capability of prediction and support for scenario analysis regarding the quality and quantity of future water resources. These models continue to grow in complexity with our ever-growing understanding of underlying system processes, their heterogeneity, and feedback mechanisms. This growth in complexity (and presumably model fidelity), however, has resulted in large, computationally intensive models with many, sometimes hundreds of "uncertain" parameters and factors whose effects on model behavior need to be characterized and understood.

The pressing need for characterizing how uncertainty in model parameters translates into uncertainty in model predictions has spawned the development of a range of methods and tools for uncertainty analysis, rooted in probability theory. In most cases, these methods are based on the two traditional, forward- and inverse-problem approaches. The former propagates assumptions regarding uncertainties in system inputs or other properties (such as parameters and/or system structure) through the model to obtain some understanding regarding uncertainties in the model predictions. Conversely, the latter uses the information contained in the mismatch between model predictions and data to help identify "good" values for the model parameters, and to characterize their associated posterior uncertainty. A third, complementary approach that has gained momentum in recent years is one based on the paradigm of "sensitivity analysis" (SA), which seeks to illuminate the controls on model behavior, thereby characterizing the dominant controls on predictive uncertainty.

The "Sparsity of Effects" principle, which originates from the Statistical Design of Experiments, states that the behavior of a system involving several variables is likely to be driven primarily by a small subset of these variables and their low-order interactions (Myers et al., 2011). This principle forms the basis of SA, whereby one aims to attribute the uncertainty in a model prediction to the uncertainties associated with different parameters, and answer a critical question: *when does uncertainty matter?* Imagine that SA could tell you the following about two example parameters in the analysis of a model: parameter A that is highly uncertain does not strongly influence the uncertainty in model prediction, while parameter B that is relatively certain strongly influences (and can therefore cause substantial uncertainty in) the model prediction. One could say that uncertainty with regards to parameter B, albeit small, is a dominant control of uncertainty in the problem at hand, whereas the large uncertainty in parameter A does not matter much. Such a characterization of uncertainty sources and their impacts is invaluable in guiding research towards reducing the uncertainties that matter, as it may point to the most important dimensions of the problem at hand.

SA methods and tools have been making theoretical and methodological advances in an attempt to keep pace with the advances in modelling and computational power. However, as pointed out by Razavi and Gupta (2015), we face two major challenges: (1) The lack of a unifying theory for SA (in particular in a hydrologic context) that places the different SA methods available in the literature on a common foundation. (2) The large, even prohibitive, computational cost of sensitivity and uncertainty analysis for high-dimensional problems and/or complex, computationally intensive models. The first challenge is complicated by the fact that existing methods seem to be based on different philosophies and theoretical definitions, as a consequence of which they may result in different, even conflicting assessments of sensitivity and uncertainty for any given problem. The second challenge is partly related to the curse of dimensionality in which, as when the dimensionality (e.g., number of parameters) increases, the volume of the problem space increases so fast (exponentially) that the available sample becomes so sparse as to be unable to properly characterize the problem space; as such, the size of the sample required (i.e., number of model runs) for a stable, robust, and statistically sound assessment typically grows exponentially with dimensionality.

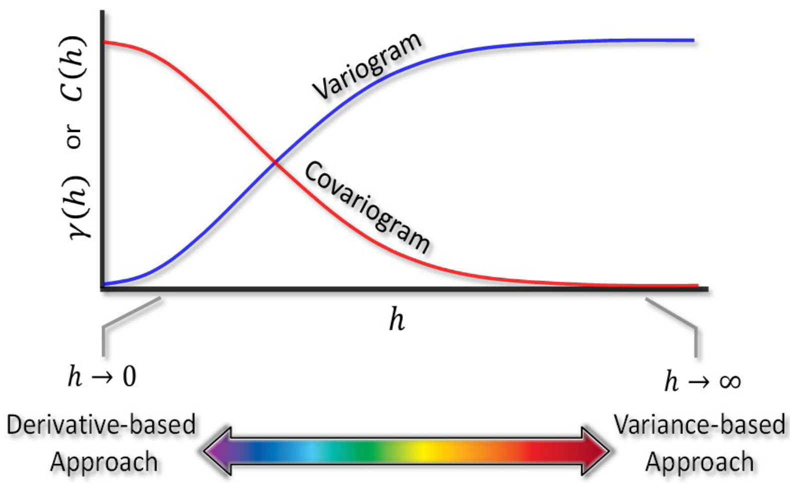


**Figure 1**. VARS is a new theory and method for sensitivity and uncertainty analysis. Using the directional (anisotropic) variogram (γ) and covariogram (C) concepts, VARS provides a comprehensive spectrum of information regarding model sensitivity, while reducing to derivative- and variance-based approaches to SA as special cases. By definition, the left end point of a varioagram (where the perturbation scale, h, is small) represents derivative information of the underlying process, while its right end point (where h is large) represents the process variance (for the detailed analytical relationships between the variogram-, derivative-, and variance-based theories, see Razavi and Gupta, 2016a). VARS encompasses the other theories and supplements them with unique metrics that characterize the spatial structure of the "response surface" of the model/process at hand.

In practice, computational cost is a major reason why most applications of SA (and of uncertainty analysis in general) have been limited to low-dimensional, simple (cheap-to-run) models. Our recent survey (unpublished) of the hydrologic modelling literature indicates that around 70 percent of reported SA applications/studies have been for models involving only 20 or fewer parameters, which falls well behind the reality of complex, state-of-the-art models. This may be seen as being *paradoxical* to the underlying goals of SA as a means to facilitate understanding the behavior of complex models and attributing the uncertainty.

In an attempt to address the above challenges, Razavi and Gupta (2016a and b) recently developed a new, general theory and method for SA called "Variogram Analysis of Response Surfaces" (VARS, Figure 1) that is designed to provide a comprehensive spectrum of information regarding model sensitivity, while encompassing the well-known and commonly used variance-based (Sobol', 1993) and derivative-based (Morris 1991) methods as special/limiting cases. Of particular interest is that VARS is highly efficient and statistically robust, providing stable results with 1-2 orders of magnitude fewer sampled points (number of model runs) compared with alternative methods. This enables VARS to tackle the curse of dimensionality and be applied to problems with hundreds of parameters. VARS has been under further development since 2016 and its software toolbox (VARS-Tool) is being continuously enabled with new capabilities.

The field of SA is still young and thriving. While further advances in this field are expected, SA needs to become an integral part of any model development, prediction, and decision-making process, providing insight into various issues such as uncertainty apportionment, parameter screening, diagnostic testing, and policy prioritization. More generally, the utility of SA may not be limited to models and their artifacts, and one may directly apply SA to data to characterize the behavior of the underlying system. Last but not the least, SA has the potential to help us deal with and isolate the "deep uncertainties" in our future water systems that occur in the context of climate, environmental, and social changes (see e.g., Herman et al., 2015).

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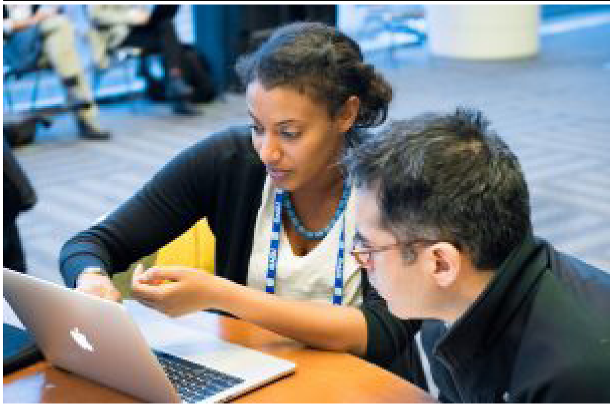

**Hydrology Section Business Meeting and Awards Reception (jointly sponsored with CUAHSI)**

DECEMBER 12

**6:30-8:30 pm**
**Hilton Riverside, Third Floor St. Charles Ballroom**

CUAHSI universities allied for water research

AGU American Geophysical Union Hydrology Section

Credits for photos on this page: AGU Fall Meeting 2017 website (http://fallmeeting.agu.org/2017/)

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AGU FALL MEETING New Orleans | 11-15 December 2017

**About the front cover photo**

Chris Gabrielli (University of Saskatchewan, 2014 Horton Research Grant Awardee) is holding a 10-m drill rod, freshly extracted from a borehole under his feet on a steep 45 degree side slope at the Maimai research catchment in New Zealand, December 2014. 40 wells were drilled up to 10 m deep from the riparian zone to ridge line to sample and monitor bedrock groundwater in an effort to better understand catchment storage and release processes and to investigate the direct influence of bedrock groundwater contributions to stream flow and streamwater age.

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