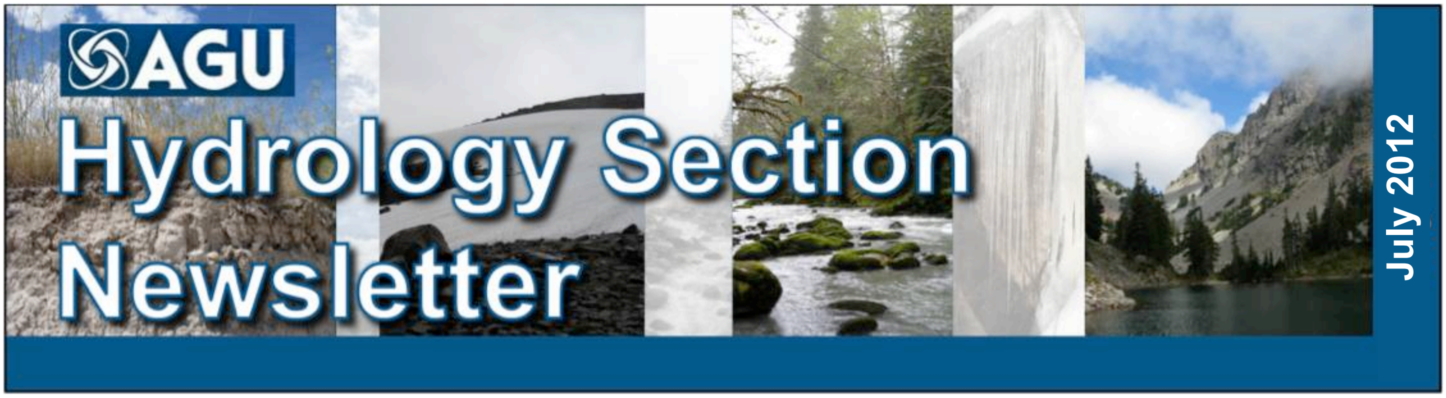
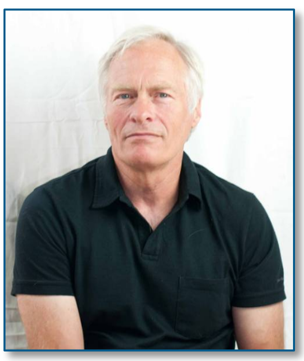


From the Section President

Dennis P. Lettenmaier (University of Washington)

We're now well into the summer of 2012. For those of us in the academic community, things tend to go into low gear in the summer – many of us are away at conferences and workshops, doing field work, or even vacationing. In any case, the treadmill tends to run a bit more slowly, and it's a good time to pause a bit and think what we're doing, and why.



At this point I could offer some deep thoughts on the meaning of the universe, but my point here is somewhat more limited. Election of new Union and Section officers will take place in the early fall. The selection of officers is one of the most important things the section membership does, and it's sad that past participation has been disappointingly low – in the last election, across the Union as a whole, the fraction of eligible members who voted was less than 20 percent, and for the Hydrology Section, it was slightly lower than that. Surely, we can do better – especially now that polling is done electronically, so there are no paper ballots to misplace.

Per our bylaws, the Section's nominating committee is chaired by the Past President (John Wilson), with four additional members appointed by me. John's committee has done an excellent job

of identifying two qualified candidates for President-Elect, and two for Section Secretary. For those not familiar with our governance structure, we elect a President-Elect to a two-year term (Jan 1, 2013 – Dec 31, 2014), and he or she will then become the President for the following two years (the procedure at the Union level is identical). The candidates for President-Elect are Efi Foufoula-Georgiou and Marc Parlange. In their articles, I've asked them to comment on some issues facing the Section, and I commend their responses to your reading before you vote (you have some time, the polls will be open September 4 through October 4). John's committee also nominated Terri Hogue and Jasper Vrugt for the Section Secretary position (this is for a two year term effective Jan 1, 2013 – there is no such thing as a Secretary-Elect!). I've asked Terri and Jasper to comment on some issues that are directly relevant to the Secretary's responsibilities, such as managing the Outstanding Student Paper Awards. Again, I think you will find their responses insightful.

When I was asked to stand for election as Section President, I contacted several of our Past Presidents, and asked them what they could tell me about the nature of the job, and what I could expect. I remember Rafael Bras in particular said to identify a few things that needed to be done, and try to focus on them and not to have my energy too diffused. That's excellent advice, which turns out to be more difficult to implement than it seems like it should be. The complicating circumstance over the last two years has been a lot of turbulence at the Union level with departure of an Executive Director of many decades and implementation of a new governance structure. In the end, I think that the effect of all of this on the Section has been somewhat modest, but it has not always been entirely apparent that this would be the case. One thing that has worked in our favor – and I have heard this over and over again – is the Hydrology Section is exceptionally well organized. I take no credit for this whatsoever – things like having a well thought through set of bylaws which prescribe how we do business (and a history of following them, at least to a great extent) have been a huge plus, and are attributable to those who've gone before me. Furthermore, our Technical Committee structure has been a huge benefit. One major push at the Union level has been to better entrain early career scientists in the governance structure. But most sections and focus groups have nothing equivalent to our Technical Committees, which effectively are an entry point for early career scientists into the Section's governance. So we've really been one step ahead of the curve there. One also finds that even the nominations process for section officers in many sections and focus groups is surprisingly ad hoc. Again, we have a well-defined nomination process, and have been able to use it to assure that the nomination process reflects the diversity within the section – by sub-discipline, gender, and geography.

So – back to my original concern about the low participation rate in past elections. I do hope that you'll all take a few minutes to read the articles by each of the candidates. This newsletter, as all past ones are, is archived on the Section's web site (hydrology.agu.org), and I intend to send out a few email reminders when the balloting opens on September 4 reminding you how to access this newsletter (if you forget, just google "AGU Hydrology Section" – the Section web site is at the top of the list).

Finally, and not related to election of officers. I want to congratulate the 30 recipients of Outstanding Student Paper Awards from the 2011 Fall Meeting. They were selected from almost 800 student presentations. I also want to thank all of you who participated in the judging, and to Secretary Martha Conklin's OSPA committee, who worked tirelessly to fill out the ranks of the judges. Martha and her committee worked closely with AGU staff to formulate a more workable judging system, which will be further refined this year. If you are willing to judge student papers in 2012, each session will have an OSPA liaison (the Session Chairs should know who they are), and you can contact them that way. I'll have more to say on this in the next newsletter, which will come out immediately before FM12.

In the meantime, enjoy your summer!

From the Water Resources Research Editor-in-Chief

Praveen Kumar (University of Illinois)

As my term, and those of the rest of the *WRR* team, nears an end early next year, please forgive me for being a bit flippant. Having handled over 3000 new manuscripts, though, a few patterns do emerge. Here are some tips for making *WRR* submissions that almost certainly will have a fast track to rejection.

TITLE: Make the title long and descriptive instead of brief and conceptual. Better yet, use (parentheses) to explain new terms within the title.

AUTHORSHIP: Don't bother to include as authors all who have contributed to the work. Also, don't take the time to consult all the included authors to get their approval prior to submission. After all, everyone will appreciate the details after the paper is published.

USE OF DATA: Feel free to use other people's experimental or field data without permission and acknowledgement. If you were able to get it, then they must not care about who uses it.

LANGUAGE: Don't take the time to check and correct for spelling, language, structure and organization, comprehension, brevity, illustration, clarity, completeness, accuracy, fallacies, etc. The reviewers can fix these details. Moreover, if they send you detailed grammatical suggestions, it means that they read the submission carefully. They wouldn't volunteer if they didn't want to help, and they are picked for their skill in copy editing anyway.

ABSTRACT: Don't make the effort to focus upon the essential contributions of the paper or the implications of the results. After all, if readers are *really* interested to know what the paper is about, they'll filter out the wheat from the chafe.

INTRODUCTION: This is all about how important your previous work is: a great way to run up your citation index. After all, if you don't, no one else will! Steer clear of the scientific context or how recent literature illustrates that this would be a novel and important contribution. The chances are that nothing interesting has been published since you began this research two years ago; so don't bother checking for recent articles. Again, this is a great use of reviewer's time – they don't have much else to do. Finally, do not waste space describing the motivation for the problem – readers can figure it out.

BORROW TEXT: Hey, this stuff already passed peer review, so it must be good! Ethical standards for publication? Fussy details. Feel free to use verbatim material from your own or other people's prior publication, and don't bother with attribution. If you must cite other work, do not place quotes around quoted material. Better yet, use the same introduction and/or conclusions you used in your last paper. Even better, try to get away with using slightly modified text from a previous paper: slap on a new title and abstract, and you are all set. If they were good enough to get published before, they'll do the job this time as well.

ACRONYMS: Use lots of acronyms. Jargon shows how "in" you are in the field, and keeps the community from stealing your ideas by understanding what you are saying. Better still, do not define acronyms anywhere, and see if the reader can figure them out. Just think of the fun your readers are having endlessly searching for what "ZYK" means. No pain, no gain. Soon they too will be writing like you do!

FIGURES: Make sure that the figures are poorly legible – can't these people be satisfied just reading the text for Pete's sake? Some tips: use small, difficult to read fonts (nothing over 8 point), clustered graphics, missing labels, data markers that make the cloud of points look like you spilled a bottle of ink, no units (anywhere), start the axis at a random number, have axis labels with lots of extra zeros on the numbers 'cause that is how Excel spits them out, and have multiple unlabeled panels. Cite figures and panels in random order – after all they *are* numbered. Further, since figures and tables are self-explanatory, it's redundant to mention their main points or provide any interpretation in the text. Remember, if one figure is good, then 10 are great. You took the time to collect the data, so plot it *all* for the world to see.

METHODS: Just stick to the cool expensive instruments; do not properly or completely describe experimental or methodological details and data. After all, who would be interested in reproducing the results or their verification? It's all about trust.

CONCLUSIONS: In the conclusions, don't discuss the role of assumptions, experimental or data limitations, uncertainties, alternative or competing explanations, limitations of the research, how the results relate to previous publications, etc. After all, why should you point out the limits of applicability of the research? That is for others to find out.

BIBLIOGRAPHY: Don't worry about missing or inappropriately cited references. Who would want to look them up? And, anyway, the technical editors will take care of that sort of thing.

DISTILLATION: Don't bother to distill and concisely explain material that is already available as a thesis or report. After all, it is the responsibility of the reader to pore through the details to figure out the main points. Once again, this is a great way to make use of the review process to figure out what can be cut out of the article.

RESPONDING TO REVIEW COMMENTS: After the reviews are received, criticize the intelligence and knowledge of the reviewers, associate editor, and editor instead of addressing the comments. After all, the reviewers are generally biased, usually incompetent, and should have been able to read the author's ideas as written "between the lines" instead of sticking to the actual written material. Above all, resist making significant changes to your manuscript – argue with the reviewers in your responses to their comments, and avoid assimilating those arguments into the text of the manuscript. And don't think of thanking them in the acknowledgements -- it only encourages them to be pickier next time.

DUAL SUBMISSION: You may never again have an original idea. Be opportunistic and submit the same material, perhaps with slightly modified title and introduction, possibly with a slightly different case study, to different journals. If the papers are in review together, no one will find out. Tip: use the "reviewers to exclude" strategically.

LEAST PUBLISHABLE UNIT: Spread out your research over several manuscripts so that each contains the least amount of information that can be published. This can be achieved by slicing the concepts, or the data so that many pieces can be presented through different avenues. The readers can assemble all the related papers to develop a comprehensive understanding. Remember: administrators can count, but not read. This is also a great way to stretch your research dollars.

THE SQUEAKY WHEEL GETS THE OIL! Don't accept responsibility for not having carefully looked at the formatting and other instructions before submission. Get right on the editors and the review team. You know they are a lazy bunch, who are just letting your manuscript gather dust. So send them repeated reminders to ensure that the paper is being attended to. After all, if it took two years to perform the research and write the manuscript, it should be exciting enough that the reviewers will drop everything else to immediately read the paper and recommend acceptance with only some mild comments.

On a more serious note, we have seen instances of all the above, which create significant challenges during the review, decision and post-publication stage. We will all be better served by authors taking a little extra care in manuscript preparation prior to submission. Language services are available through AGU (http://www.agu.org/pubs/authors/) to ascertain that reviewers can focus on the scientific essence of the papers. Electronic screening of submitted manuscripts is already resulting in rejections where there is significant overlap of previously published material (see agu.org/pubs/crossref/2011/2011EO130008.shtml).

The above was written with contributions of the WRR Editorial Team with the hope that we will all pause and spend a little extra time to ensure that everyone has a pleasant experience as we communicate important and exciting science to our peers and to society.

Finally, AGU is looking at new models of publication. I encourage you to read Union President Mike McPhaden's message (http://www.agu.org/about/presidents_msg/)

regarding AGU's plans to work with an external partner for the production and logistical aspects of the publishing process, and if you have concerns, to make your feelings known.

Also, my editorial team is in the final year of its four-year term, which will end on March 31, 2012. In order to ensure a smooth transition, a search committee for a new Editor in Chief has been appointed and has been tasked to complete the selection by October 31, 2012. The EIC job description, as approved by the Council in December 2011, can be found at agu.org/pubs/journals/pdf/AGU-EIC-Description.pdf. For nominations (including self-nominations), please contact Professor Efi Foufoula-Georgiou (efi@umn.edu), Chair of the search committee.

The value of long time series in hydrological research

Tim Burt (Durham University, UK)

It is a huge honour and privilege to be elected an AGU Fellow, especially as an international member. I am especially grateful to those who nominated me. I would also like to thank all those

with whom I have collaborated over the years, in particular my PhD supervisor, Malcolm Anderson, right through to Nicholas Howden and Fred Worrall with whom I work a lot today. Literally, as I was starting to write this piece, a prospective student from China wrote the following in an email: "brilliant teachers usually change the destinies of students." How right she is, and I myself have been very lucky. At high school I was taught by an inspirational geography teacher, Jim Hanwell. He got me hooked on physical geography. At Cambridge I was much influenced by the late Professor Richard Chorley, who encouraged a broad perspective across physical geography, from meteorology through to geomorphology. It is interesting that there has been a recent resurgence in the use of the word *hydroclimatology* (see Randal Koster's piece in the July 2010 Newsletter, for example); Dick would have approved! Whatever words we use to describe our broad research area – and *geophysical* is as good as any – it seems to me that placing hydrology within a broader context is always the best thing to do. There can be dangers and limitations in narrow, reductionist science. Here, I want to follow on from the comments made by Mary Jo Baedecker in the December 2011 Newsletter. She commented that "models are only as good as the data on which they are based. Reliable physical, chemical, and biological data are needed to meet the environmental challenges associated with: water distribution and use". The continued need for reliable data implies a requirement to maintain monitoring networks, in particular benchmark stations with exceptionally long records. Some time ago I commented that the importance of long-term observation of the natural environment has been recognized for a long time, and yet "monitoring" is often dismissed as low-grade science which can contribute little to our understanding (Burt, 1994). I think things have improved since then, in that the value of high-quality data is increasingly recognised as a complement to modelling efforts. However, this may be something that is well recognised by researchers but not so much by the government agencies that maintain our observational networks. For them, especially at times of reducing budgets, the cost of collecting data can seem excessive and something easily cut, without considering the worth of the continuing record. Maybe a long hydrological record is another example of an environmental good that is hard to put a price on? So, why do I think long records are particularly valuable? Among its eight definitions of the word monitor, the *Shorter Oxford English Dictionary* includes "something that reminds or gives warning" and "(to) maintain regular surveillance". Whilst "monitoring" could imply actions that are pointless, "surveillance" suggests a deliberate plan of action. I think there are three benefits of having long time series available:

Long-term data reveal important patterns for scientists to explain, allowing trends, cycles and rare events to be identified. This is particularly important for complex systems where signals may be subtle and slow to emerge. Subtle processes are embedded within highly variable systems so that their weak signal cannot be extracted from a noisy background without a long record. In systems jargon, the signal-to-noise ratio is low. Though a clear pattern may eventually exist, high-frequency variation will obscure this, and short-term study will be unable to identify it. Such problems are typical of climatic systems: there is no way to distinguish a normal extreme from an entirely new trajectory without resort to a long time series. Figure 1 shows an example: the UK Meteorological Office (UKMO) includes a number of very long climatic records for "historic stations" on its website (http://www.metoffice.gov.uk/climate/uk/stationdata/). Here winter rainfall (December through February) at Southampton is compared to the North Atlantic Oscillation Index (NAOI) for the period 1856-2000. In the uplands, there is a strong, clear signal between NAOI and winter rainfall, reflecting the varying strength of the North Atlantic atmospheric circulation. In the lowlands, there is usually no significant correlation. The Southampton record is interesting because eventually a significant correlation emerges – but it needed 145 years to achieve it! OK, the correlation is low ($r=0.195$, $p=0.018$), so the R^2 value indicates that only a very small amount of the variance is explained (3.8%). This is not the point: there is a hint that a significant relationship exists even at low altitudes and this could be a starting point for further investigation, looking at other long rainfall records in the region. Fortunately, there are several, although why UKMO has no data for Southampton after 2000, I do not know. This is just the sort of benchmark record that needs maintaining. This leads on to a second point:

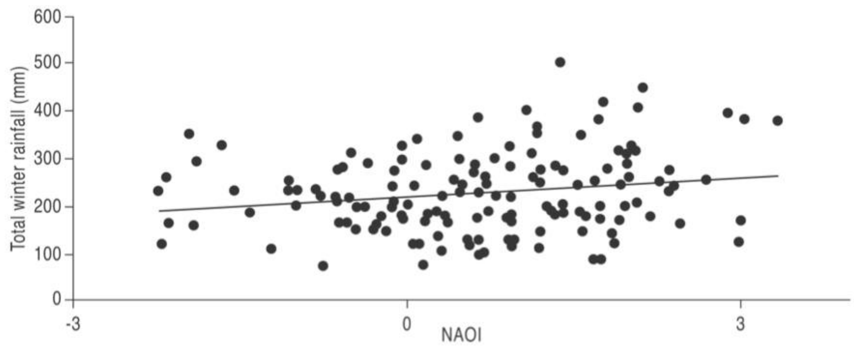


Figure 1: Winter rainfall at Southampton, England, in relation to the NAOI, 1856-2000.

Long-term data sets are essential for testing hypotheses undreamt of at the time the measurements were started. Figure 2, which plots monthly means of water colour for the River Tees (Worrall et al., 2003), shows how our perspective changes as the record lengthens. For a brief record of just a few months, often the sort of timescale for PhD fieldwork, we have little idea what the record might mean. As the record lengthens, we can detect seasonal cycles and gradually the scale of inter-annual variability emerges. We may detect some unusual or rare events, perhaps a drought, but we may have little idea how unusual this episode might have been. Only with the long-term perspective can we begin to detect long-term trends. It seems that anything less than 12 years simply indicates the result of climatic variability; trends can be more reliably identified as the series lengthens and climatic noise becomes relatively less important (Howden et al., 2011a). The daily record of water colour for the Tees is one of the longest available. As a proxy of dissolved organic carbon, the long series reveals an intriguingly linear trend, within which post-drought episodes could suggest extended disruption to blanket peat after it dries during a severe drought and then re-wets, but it might equally reflect additional leaching in wet years. Peat-covered catchments tend to be larger sinks for carbon in relatively dry years and smaller sinks in wetter years, the latter giving rise to higher export from the catchment, with increased losses of DOC, POC and dissolved CO_2 (Worrall et al., 2009). Although there is additional biogeochemical production of DOC as a result of drought, the dominant control of DOC flux is runoff production, overprinting an underlying increase in trend in DOC production which is consistent with increases in air temperature and atmospheric CO_2 (Worrall and Burt, 2007).

Monitoring is an essential way of discovering whether there are significant undesirable changes taking place. This was not the original justification for monitoring programmes, which were usually designed to indicate average conditions, but programmes like LTER (USA) and ECN (UK) were established with change in mind. Figure 3 shows, paradoxically, an unwelcome lack of change. Despite fertiliser application rates having peaked in the early 1980s and despite legislation to reduce nitrogen losses from rural and urban areas alike, nitrate concentrations in UK rivers remain obstinately high, an indication of the relatively long residence times of groundwater (Howden et al., 2011b). A disjunction between policy-initiated change and response several decades later lies well beyond the usual time span of political action! Perhaps the most important conclusion is that monitoring systems must be adequately maintained over long periods - records of less than two or three decades may well be of little use. No long-term record should be discontinued without proper consideration of its ongoing merits, and protection of a few benchmark sites is essential (Burt et al., 2011).

A final thought about long time series. Having collected the data, very often at the tax payers' expense, it is important that the data are visible and accessible. Too often, at least in the UK, those holding the data are neither friendly nor cooperative. Even if available, quality control can be poor, databases deliberately labyrinthine and data licences unduly restrictive. So I salute organisations like the H J Andrews Experimental Forest (USA) and the National Rivers Flow Archive (UK) for their friendly and generous approach - and it pays off, since this makes student projects easy (which can only be a good thing), whereas, if the data are hard to access, they will look elsewhere and follow other ideas. I don't know if the term "train spotter" is a familiar one in the USA. I was one as a kid, collecting the numbers of steam engines as they passed through my local station. Maybe it shows ...

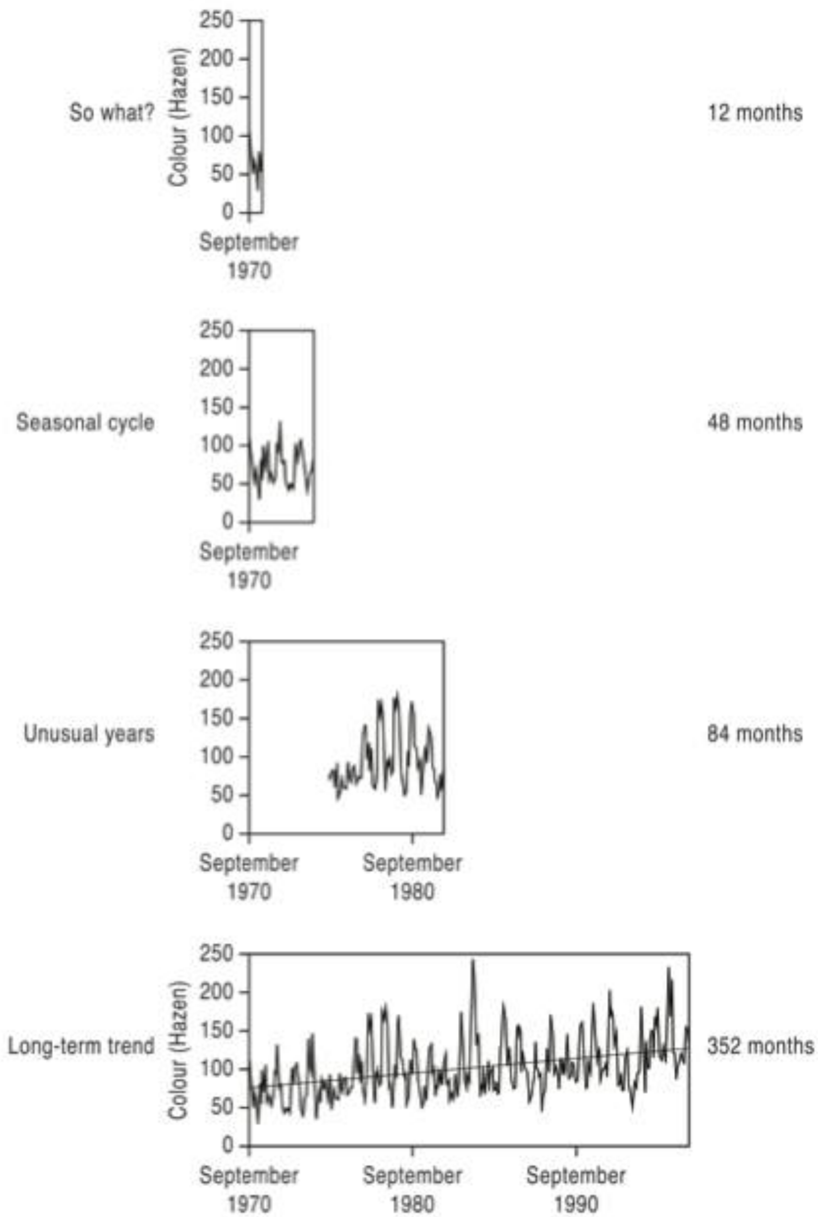


Figure 2: Observations of mean monthly water colour for the River Tees, England, demonstrate the importance of a broad temporal scale of analysis.

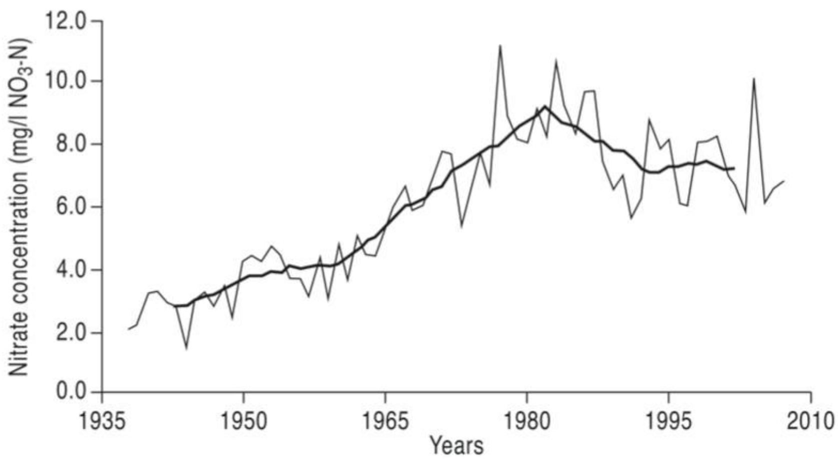


Figure 3: Nitrate concentrations for the River Stour, Essex, England, 1937-2007.

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Rallying around our known unknowns: What we don't know will hurt us

Jay Famiglietti (University of California Irvine)

Given a rare opportunity to communicate to our section, I want to focus this note on some key things that we don't know and can't do, rather than patting ourselves on the back too much.

But first … a little back-patting! For context, here's some background on what we do in my group. First, we work to make the hydrology in climate models, like those used in the IPCC, increasingly more realistic. Second, we use satellites to explore how the water cycle, and with it, water availability, is changing. The community that works on these issues is not large, but it is dedicated. There is no question that we should be proud of our advances over the past couple of decades. For example, we can now simulate the water cycle with improved accuracy across multiple scales. Our computer models, from the hillslope to the GCM scale, run at higher resolution, with greater fidelity, and provide unprecedented insights into process interactions, while enabling new science (e.g. Wood et al., 2011).

Likewise, satellites have revealed that the pace of water cycle change is greater than we thought, and not surprisingly, that the human fingerprint on our water landscape, due to water use, water management and land use change, is severe, and is global in scope.

We're making great progress as a community. That's for certain. However, observations from the Gravity Recovery and Climate Experiment (GRACE) mission (Ramillien et al., 2008), and my involvement with CUAHSI, have forced me to confront some key issues that I don't believe that we are prepared to address. For example: how can we expect our models to simulate the synoptic patterns of water storage changes that we see from GRACE (Syed et al., 2008), which are in large part human driven, if water management practices (e.g. groundwater pumping, irrigation, reservoir storage, conveyance) are not well represented (or represented at all in some cases) in our land surface models (e.g. Pokhrel et al., 2012)?

In parallel, my work with CUAHSI on the Community Hydrologic Modeling Platform (CHyMP) (Famiglietti et al., 2011) has greatly raised my awareness of other critical unknowns on the data side. In short, in my opinion, our nation's hydrologic modeling assets are simply not up to the task of addressing our most pressing societal issues of food, energy, water and national security. We are behind where we need to be, and we are falling behind other nations.

To illustrate, here are a few of what I've been calling the 'unfortunate realities' of modern hydrology.

We don't know how much fresh water we have on land. Not stored as groundwater, or surface water, as soil moisture, or as snow (e.g. MacDonald et al., 2012). Believe it. It's true. Many estimates, for example, of continental scale groundwater supplies, are simply guesses based on ad hoc assumptions (Korzun, 1978). Others are reports of water storage in man-made reservoirs. It is unclear to me how we can address sustainable water management without knowing how much water is actually on and in the ground.

Our knowledge of Earth's surface and shallow subsurface, i.e. its water environment, including its digital representation, remains appallingly insufficient. At the surface, we know little about the bathymetry of rivers and lakes. We have no idea how deep our soils are, at least at the larger regional, national and global scales. While two-dimensional maps of global hydrogeology are now available, the third dimension, as well as basic aquifer parameters, remains a mystery at national and global scales.

Our global monitoring system…for river discharge, for groundwater extraction, for water use…is insufficient for tracking even the most fundamental changes in water storage and availability. It doesn't have to be that way, but for a host of political and socioeconomic reasons, it is.

To review then: we don't really know how much water we have; we don't have a detailed picture of our water environment; and we don't do such a great job of measuring its storage and flows within it. How in the world have we let this happen?

I believe it's because we haven't rallied around core questions of societal relevance. The typical excuse that we give is that -- these are not science questions. Or -- these are too applied. However, we can no longer afford the luxury of such academic arrogance.

Every single one of us works on some aspect of sustainable water management. But let's face facts: we simply cannot manage water sustainably until we can answer the following three questions. How much water do we have -- as snow, surface water, soil moisture and groundwater? How much do we need -- for humans and for the environment? And, how are these changing with time – with climate change and with increased understanding and adaptation? Society wants to know. We can provide the answers, and virtually all of our research fits under this broad umbrella of water sustainability.

It is time for us to move forward with core observations and models that can utilize them to predict and help prepare for the future. Getting there requires both top-down and bottom-up engagement.

From the top, commitment and focus is required at the national and state agency levels. Vision and leadership is required at the program manager, division and directorate levels. We must make a significant investment in the tools – namely models, observations and data products, and information systems – to enable the critical science, applications and solution strategies that society demands, and that our community is capable of delivering.

From the bottom, it behooves us to rally around key societal questions including the known unknowns discussed above. And we must recognize that it is our responsibility to communicate these key issues, in order to educate our elected officials and to motivate their support. Other communities do it. It's time for us to do so as well.

More broadly, our public, our teaching, our research, and our environment, will be best served if we embrace the communication challenge of elevating water issues to the level of everyday understanding.

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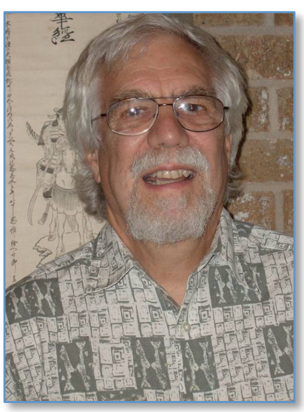
Consistent microwave radiances for precipitation retrievals

Thomas T. Wilheit (Texas A&M University)

It should come as no surprise to the hydrological community that sampling is the principal error source in measuring precipitation from space using microwave radiometers. The temporal and spatial variability scales of precipitation are notorious. Admittedly the infrared (IR) sensors on geo-synchronous satellites can provide a great deal of sampling, but the measurement physics are not robust. The dense sampling does, to some degree, compensate for the weak measurement physics, and the products are useful for some applications. The IR precipitation product is complementary to the microwave product, which has a more direct physical connection to precipitation.



The Tropical Rainfall Measurement Mission (TRMM) has supplied a wealth of information about precipitation at latitudes lower than 40 degrees but it is still limited by sampling. In a world of unlimited resources, we would simply launch a constellation of dozens of satellites to address the temporal sampling problem; this is well short of practical in the real world.

On the other hand, there is at least a handful of satellites with microwave radiometers suitable, if not ideal, for precipitation measurement. These include the European METOP, U.S. NOAA and DMSP, and the Chinese FengYun-3 (FY-3) operational series. Experimental satellites such as TRMM, U.S. Navy Windsat, French Megha-Tropiques, Japanese GCOM-W and, until recently, NASA's AQUA have microwave imagers even better suited to precipitation measurement. However, no measurement is perfect and each sensor has its own unique set of problems. Simply combining the sensors would produce a precipitation record severely contaminated by sensor-to-sensor differences.

This is where the Global Precipitation Measurement mission (GPM) comes in. The concept is to tie this disparate set of precipitation measurements into a coherent whole. The GPM Core satellite, a joint project between the United States and Japan, will be launched into a medium inclination (65°) orbit that will have many crossings of the other satellite orbits at a wide range of latitudes. It will carry a high quality microwave imager, the GPM Microwave Imager (GMI), and a Dual frequency Precipitation Radar (DPR) and will provide a wealth of data for comparison with the constellation radiometers. With this payload, the consistency among the various precipitation retrievals can be addressed in two ways. The first is by appropriate comparisons; the radiometric calibrations of the various microwave radiometers can be adjusted to be consistent. The second is that the GMI and DPR can be used together to generate a hydrometeor database that will be used in a common framework for precipitation retrievals from all the sensors in the constellation. This note is concerned with the first of these; the second is listed for context. Currently we have TRMM and several polar orbiters; they could be considered as a prototype for the GPM system.

Precipitation can be measured by microwave radiometers through two mechanisms: the emission of microwave radiation by liquid hydrometeors and the scattering of microwave radiation by frozen hydrometeors (Wilheit, 1986). The emission mechanism has a number of technical advantages, but is only useful over a water background due to its high reflectivity. The scattering mechanism can be useful over land and provides some additional information in deep convection over the ocean and for frozen precipitation. Although the scattering mechanism is a more direct measure of precipitation than the IR measurements, there are a number of issues that make accurate retrievals difficult. One of these, the varying emissivity of the land surface, is being addressed by hydrological modeling within the GPM community (Ferraro, 2012).

In order to compare the radiances measured by different sensors with similar, but not identical, frequencies and view angles, we need an algorithm that produces synthetic observations of a target sensor from actual observations of a source sensor. The Intersatellite Calibration Working Group (a.k.a. X-CAL) of GPM depends on having several teams taking different approaches to this translation. To the extent that the results are similar, confidence in the process is enhanced.

In order to infer a linear transformation to a common reference standard calibration, two points are needed. The oceans provide a low brightness temperature point and heavily vegetated surfaces such as the Amazon Basin provide a high brightness temperature. At this point we only have a single viable algorithm for the warm end—that of the University of Michigan (UMI)—but four teams currently contribute cold-end algorithms. Three of the teams Texas A&M (TAMU), University of Central Florida (UCF) and Colorado State University (CSU) make use of the frequent crossovers between the low inclination satellite (TRMM now, GPM core in the future) and the polar orbiters. These provide co-located, nearly simultaneous observations for the source and target sensors. For these comparisons, the data are averaged over 1° x 1° boxes. The allowable time difference and other filters vary from team to team. A fourth team at UMI uses global histograms of brightness temperature for the comparisons.

The UCF team uses weather forecast model analyses, specifically the Global Data Analysis System (GDAS) from NOAA, to compute radiances for both the source and target sensor. Here there is no real distinction between the source and target. CSU uses the radiances from the source sensor, an externally supplied sea surface temperature and covariance constraints to infer the precipitable water, cloud liquid water and surface wind speed from which the radiances for the target sensor are computed. The TAMU algorithm is conceptually similar to the CSU algorithm but it retrieves the sea surface temperature from the radiances rather than using an externally supplied value and makes different assumptions about the atmospheric structure. TAMU has also recently implemented an algorithm similar to that of UCF to facilitate detailed comparisons of the performance of the two types of algorithms. The UMI algorithm uses global histograms to extrapolate to a global minimum brightness temperature for each channel of the sensors and connects the source and target minima via a model.

All these algorithms depend on radiative transfer models. Over the ocean the models are reasonably good, over land somewhat less so. The models are, however, not perfect. If they were, this process would be easier. We would simply gather some ground truth and calibrate to the models. Since the models we are forced to use are imperfect, we need to minimize the impact of the model choices. The X-CAL team uses double differences as expressed in equation [1] to minimize this impact.

$$\Delta TB = TB(TGT,Obs) - TB(TGT,Calc) - TB(SRC,Obs) + TB(SRC,Calc) \qquad [1]$$

Where ΔTB is the calibration difference between corresponding channels of the Source (SRC) and Target (TGT) sensors. Obs and Calc denote observed and calculated. In this formulation, the model errors very nearly cancel out. We have looked at model uncertainties, and it appears that the impacts are of the order 0.1 to 0.2K for typical differences in the frequencies and viewing angles of corresponding channels.

Figure 1 shows a typical example of the ΔTBs between Windsat and TMI found by four teams over the radiometrically cold open ocean. The range of offsets is only about 0.4K peak-to-peak for the 10.7 GHz horizontally polarized channel and of a similar magnitude for the other channels common to TMI and Windsat. At the warm end (over the Amazon Basin) only the UMI algorithm was satisfactory. The dashed black line represents a unified delta produced by averaging the CSU, TAMU and UCF results at the cold end and using the UMI value at the warm end. Similar unified deltas were generated for all the TMI channels from 10.7 GHz to 37 GHz. Windsat did not have an appropriate channel for comparison with the TMI 85.5 GHz channels.

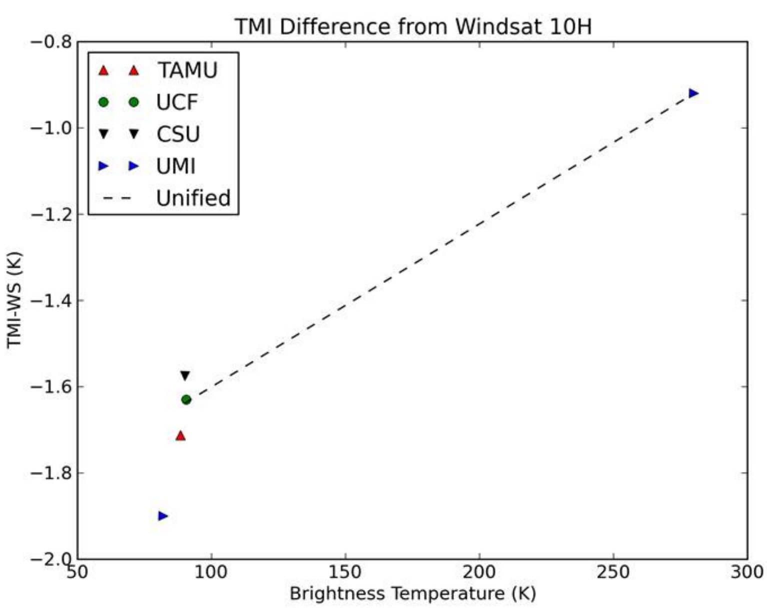


Figure 1: Calibration differences between TMI and Windsat 10GHz Horizontally polarized channels as determined by 4 teams, Texas A&M University (TAMU), University of Central Florida (UCF), Colorado State University (CSU) and University of Michigan (UMI).

Having established the differences between TMI and Windsat to something on the order of 0.1K accuracy, which is right? Neither is perfectly right nor absolutely wrong. There are no absolute standards for radiances in orbit. However, the intended mission for Windsat, looking for wind direction signals in the small anisotropy of oceanic radiances is extremely demanding on calibration accuracy. Accordingly the pre-launch design and testing of Windsat concentrated heavily on calibration accuracy and stability. An extensive post launch evaluation including special spacecraft maneuvers further refined the calibration. TMI also was designed and tested to be well calibrated and had its own post launch evaluation, albeit to a lesser degree than Windsat. So both should reflect some insight into calibration, but one would expect Windsat to be better calibrated. An optimal combination, weighted as the inverse square of the uncertainty of each, should have a better calibration than either separately.

With no calibration standards, there is no direct way of assigning the uncertainties needed for the weighted averages. The X-CAL team has arrived at a method of estimating the weights. It is not ideal, but it is all we have right now. Two of the algorithms for computing the cold end deltas (TAMU and CSU) adjust geophysical parameters in a geophysical radiative transfer model to match observed radiances. At the warm end, the UMI algorithm does the same. The statistics of the TAMU cold end algorithm residuals are shown in Figure 2. What is shown is a cumulative probability distribution of the residuals of the fits (in K^2) for TMI and Windsat. We can see, for instance, that about 80% of the TMI fits matched the observations to 1 K^2 or better. The Windsat fits were, typically, about a factor of 3 better than the TMI fits. That is to say that Windsat is more consistent than TMI with the radiative transfer models used, thereby confirming our preconception that Windsat's calibration was more accurate. At the warm end, the UMI model gave a very similar result. On this basis, the X-CAL team chose to weight Windsat three times as heavily as TMI in a Consensus Calibration. (CC_1.1). This is described in more detail in Wilheit et al. (2011). TMI recalibrated to CC_1.1 was run through the TAMU algorithm and the results are also given in Figure 2. It would be tempting to cite this as evidence that the Consensus Calibration is better than either TMI or Windsat, but there is more to the story. Two of the algorithms (TAMU and CSU) compute deltas that nudge the radiances towards consistency with the model so they are, in some measure, gaming the testing method; this makes the result a little too good to be true.

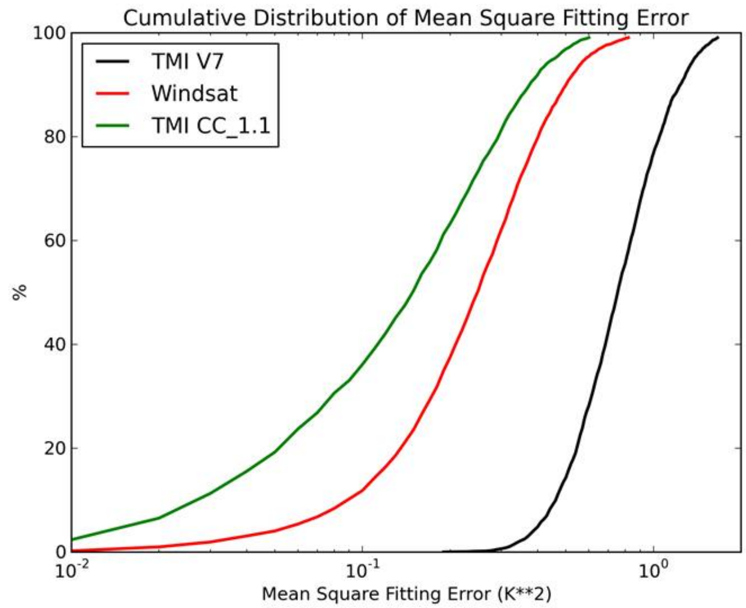


Figure 2: Cumulative Distribution Functions of residuals of TAMU fitting algorithm as a measure of consistency with a radiative transfer model for TMI (Version 7), Windsat, and TMI recalibrated to a consensus calibration standard (CC_1.1).

The X-CAL team has also computed adjustments to make AMSR-E (JAXA version) consistent with CC_1.1 and preliminary adjustment values values to convert the SSM/I Fundamental Climate Data Record (Beta version) from Colorado State to CC_1.1. We are currently working on adding SSMIS to the list and are looking forward to getting data from the recently launched GCOM-W and Megha-Tropiques satellites.

Although it is not discussed here, GPM also plans to use channels near 183 GHz, normally associated with profiling water vapor, for snowfall detection. We have analogous efforts to cross calibrate the water vapor sounders on operational NOAA, NPP and Metop satellites using 183 GHz channels on the GMI instrument.

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President-Elect: Efi Foufoula-Georgiou (University of Minnesota)

The year was 1983. I had just finished my master's thesis at the University of Florida, Gainesville, and I was excited to present my results at the AGU meeting and meet all those people whose papers I was reading so voraciously! My talk was scheduled as an oral presentation (no posters at that time) at 5 pm on Friday (the last talk of the meeting – no one knew my name.) To my surprise, the room was packed (no parallel sessions) and my talk (handwritten transparencies) went very well. I must have put 30 hours of intense effort into that 12 minute talk! This is a personal story portraying the Hydrology Section and the way in which a young scientist could get noticed some 30 years ago. Of course, times have changed, and our field has grown in size and complexity - but the science is even more exciting, and the problems we must address are more pressing than ever: from climate, to water availability, to deteriorating landscapes. I am honored to have been asked to serve our community in the capacity of President of the Hydrology Section. If elected, my top priorities will be: (1) enhancing the scope, visibility, and interdisciplinary linkages of our science; (2) nurturing the next generation of hydrologists through improved networking, mentoring, and recognition; (3) improving AGU's communication vehicles and fostering new opportunities for partnerships, including those with appropriate international organizations. So what experience do I bring to the table to make progress on these priorities?

First and foremost, I am a long-time and devoted AGU member. I have published on challenging problems in hydrology, while educating talented young scholars in whom I take enormous pride. Second, I have served the hydrologic sciences community in many ways – for example, as Chair of the Board of Directors of the Consortium of Universities for the Advancement of Hydrologic Sciences (CUAHSI)—and have worked hard to promote community growth. Third, I have served as Director of the National Center for Earth-surface Dynamics (NCED), an interdisciplinary NSF Science and Technology Center. Through NCED, I have personally witnessed the difficulties in building true interdisciplinary research teams, as well as the many benefits that result from a sustained effort. I have used myself as a "guinea-pig" and have "transformed" (using the NSF term!) my own research, first working with geomorphologists, ecologists, mathematicians, and atmospheric scientists to address challenging problems from new perspectives. This has been a very enlightening and valuable set of experiences for me. I've learned, for example, that the best interdisciplinary research is not imposed from above but is led from below with the combination of scientific excitement and deep disciplinary knowledge.

My commitment to the next generation has led me to support many community initiatives, such as the NCED Young Affiliate Science Program and efforts to engage Native Americans in the Geosciences. This work has led, in collaboration with Salish Kootenai College, to the establishment of the first Water Sciences degree program in a tribal college. As the "globalization of science" proceeds, AGU must foster connections and collaborations across national borders. I know that our community is ready to engage more vigorously on the international stage, and I believe that purposeful leadership by the AGU section is needed in this regard.

Finally, my current membership in the AGU Publications Committee has made me acutely aware of the vast changes that AGU is undergoing as an organization. A voice in the AGU Council from our Section, as represented by the Section President Elect, is very important, and I am committed to be an open-minded but critical filter of impending large changes in our journals and elsewhere in the Union. As NCED enters its last year as an NSF-funded center, I am ready to put my energy into the community represented by the AGU Hydrology Section, and I hope that my experience and dedication will be a positive force. I want to finish with a quote that eloquently captures the need to continue working at the frontiers of the hydrological sciences, across relevant disciplines within our section, across AGU sections, and across continents, for meeting the challenges ahead of us in understanding and predicting environmental change:

> "*If we believed that the Earth was a constant system in which the atmosphere, biosphere, oceans, and lithosphere were unconnected parts, then the traditional scientific fields that study these areas could all proceed at their own pace treating each other's findings as fixed boundary conditions. However, …*" NRC (1983).

We now need to work together to fill in the rest of this quote with excellent fundamental and interdisciplinary research: discovering and disseminating new knowledge and building needed human capacities along the way. Thank you again for the opportunity to serve.

President-Elect: Marc Parlange (École Polytechnique Fédérale de Lausanne)

The Hydrology Section of AGU is the primary professional home for many hydrologists around the world. I know the AGU hydrologic community well, having served as the Hydrology Section secretary and Editor-in-Chief of *Water Resources Research*, and I plan to use my experience for its betterment. The AGU hydrology community is an intellectually open and welcoming environment with increasingly broad international community engagement and is the main society for discussion of scientific advances in hydrology. My recent experience at *WRR* gives me great confidence in the dynamic community spirit and vigor of the Hydrology Section. This is evident through the superb new science being submitted to the journal, the deep and extensive peer reviews by thousands of our international colleagues, and the dedicated hard work of all the associate editors, editors and journal headquarter staff to help authors make the most of their research efforts. I was pleased that we were able to increase the involvement of many international associate editors; water research clearly knows no boundaries and continually broadens its scope. Similarly when I was Section Secretary and helping to organize student judging, I was most impressed by all the selfless time given by the entire community during the meetings to provide help in assessing student presentations.

I am honored to be a candidate for President-elect of the Section and look forward to working hard on behalf of the entire community. Our AGU membership in water research, broadly defined, continues to grow; thus, it is important to both expand the active participation of current and new hydrology members in the life of the Section and also maintain the warm sense of community the Section provides. As President, I will strive to continue the fantastic work of the previous presidents and many members of our community in welcoming new members to the Section and encouraging their participation in the technical committees, ad-hoc and medal committees, organizing and chairing sessions at the annual meetings, and reviewing and editorial participation with the union journals, especially WRR. As we have grown, the biannual newsletter started by Dennis Lettenmaier, along with the organization of award presentations in conjunction with the Langbein Lecture, has been instrumental in increasing the communication of activities within the Section. Continuing this, as well as implementing regular town hall meetings, which have occurred sporadically over the years, will allow broader awareness and membership participation on evolving topics of current concern.

I look forward to continuing with renewed energy my predecessors' efforts to promote and recognize excellence in hydrologic research and lifetime achievements. When I was Editor of *WRR*, our motto was "*the sun shines for all;*" we wanted it to be clear that the journal was all-encompassing and that quality research in all domains was welcomed. We invited leading Associate Editors from around the world, including previously poorly represented regions (e.g., South America, Asia, Eastern Europe) and in all fields of water resources research. We felt strongly that the journal's mission was to be the prime hydrology journal worldwide, open to the community in the broadest sense, ready to promote and encourage the new hot spots of research, especially across disciplines – in essence, to be the ultimate society journal. I believe this philosophy of inclusion and openness is also critical in the Hydrology Section. For it to thrive, we need to draw on the full richness, diversity and depth that our community has to offer. It is extremely important that limited groups or sub-domains of hydrology do not become primary community representatives. The focus groups are playing an important role in supporting and enabling hydrologic research, as are other Sections, especially Biogeosciences and Atmospheric Sciences, and it is important to reinforce these hydrology-related connections in AGU. I will work to draw on the entire membership of the AGU to focus on true academic quality in nominating our colleagues for Section and Union awards, AGU Fellowships and medals. I look forward with great enthusiasm to helping to continue the fine work of the Section, which has been a source of inspiration throughout my career.

Section Secretary: Terri S. Hogue (Colorado School of Mines)

I currently am an Associate Professor in the Civil and Environmental Engineering Department at the Colorado School of Mines (CSM). Prior to joining CSM, I was a faculty member in the Department of Civil and Environmental Engineering at UCLA for eight years. My research focuses on the understanding and prediction of hydrologic fluxes to improve management of water resources, to assess human impacts on the environment, and to mitigate the effects of natural hazards. Specific projects in my group focus on urbanization and sustainability, climate variability and watershed response, catchment response to wildfire, watershed modeling, and remote sensing of land surface properties. My recent awards include NSF Faculty Early Career Development (CAREER) Award, AMS *Journal of Hydrometeorology* Editor's Award, several teaching awards (UCLA Northrop Grumman Excellence in Teaching Award and twice UCLA-ASCE Professor of the Year), and an invitation to speak at a "Hazards on the Hill" event at the U.S. Senate. AGU has been an integral part of my career since my early days in graduate school at the University of Arizona. After many years of participation in the Surface Water Committee, I was appointed deputy chair, serving from 2007-2009. I was appointed chair in 2010 and will serve through this December. I am also a reviewer for various AGU journals and have been an associate editor of the AMS *Journal of Hydrometeorology*. Having "grown-up" in AGU, I believe the engagement of young scientists is critical to ensure a dynamic and diverse membership as we move forward. The Outstanding Student Paper Award, a key pathway for student involvement and recognition, has improved greatly since my early involvement in AGU. Although we are no longer running from session to session delivering batches of forms and

trying to solicit judges (my experience in 2006 as co-chair for the Fall Meeting), the process still needs member support and streamlining. We saw significant advances in the planning and implementation of judging for over 800 student papers at the last Fall Meeting. The digital signup has significantly improved member response; however, commitment and buy-in from session organizers is critical to strengthen judging quality and assure success. A key role of the Section Secretary will be to work with the new Executive Committee and Technical Committee chairs for ideas on how to facilitate engagement of session conveners in the judging process. Feedback and iteration with the committees and members is critical for improvement. I also believe more student engagement in the Technical Committees is needed. Following the AGU Council approach, we might consider official student representatives on the Technical Committees, drawn from member and committee suggestions. We also need to put more effort into including graduate students and early career scientists in session planning for the Fall Meetings. The last few years have seen significant changes in AGU's executive structure. The excitement and progress are evident at meetings and in AGU's broader interaction with the public and scientific community. In the Hydrology Section, Dennis has made great strides in keeping us informed of ongoing AGU and Technical Committee efforts through his leadership and the hydrology section newsletter. As Secretary, I will continue to support ongoing efforts by leadership and the technical committees and assist in facilitating cross-collaboration between these groups. I also will promote early planning of shared sessions and encourage our section members to organize Chapman conferences on cutting-edge topics in the hydrologic sciences. I also intend to continue to promote the inclusion of a diverse AGU community in committees, conferences and session planning.

Section Secretary: Jasper Vrugt (University of California Irvine)

Let me first thank AGU and its leadership for asking me to run for the secretary position of the Hydrology Section. This is a humbling opportunity, and if elected, I will do everything I can to serve our section and AGU well. An easy strategy that might convince you to vote for me is to promise each of you a few hundred dollars, but, instead, what I'd like to entice you with is something different. Our section faces several challenges. First, the steady growth of our section has increased the number of sessions proposed by organizers. Each of

these session proposals is emailed around and carefully reviewed by the different Technical Committees, a daunting task that requests significant time and effort of the chairs and members. I will work closely with our Section President (Eric Wood) and AGU leadership to find more efficient solutions. For example, we could consider using an online system where each session proposal can be uploaded and reviewed. This would make reviewing easier for the Chair and members of each Technical Committee. Evaluations (numerical scores) and feedback (if desired) could be disseminated rapidly to the individual session proposers, and those that rank highest would be selected. Secondly, the AGU Outstanding Student Paper Award deserves careful attention. Practical experience suggests that it is difficult to find a sufficient number of colleagues to review each student poster and/or presentation. A better allocation model needs to be adopted and implemented to ensure adequate review. I will work with all of you to ensure a fair and rigorous evaluation of the student competition. Each co-author (non-student) participating in the student competition could be asked to review at least one or two other contributions in other sessions not directly aligned with the topic of their respective submission. Alternatively, the student or advisor could be asked to arrange for other viable judges. Those that do not adhere to this policy might not be considered for an award. Unfortunately, we can only successfully run a competition of this size if those who request their work to be evaluated actively participate in the review of other submissions. Finally, I would like to find an efficient solution to minimize session merging (after submission of abstracts). The program committee does an outstanding job in arranging sessions (prior and posterior to abstract submission – had to use at least some of my research jargon in here!), yet I believe further refinements can be made. I feel that our program should contain a larger number of predefined session topics that are known to be important and timely. A smaller number of larger sessions with different subtopics would most likely attract larger audiences and would have a bigger overall impact than several smaller sessions. These are merely a few efforts and ideas to maintain and further enhance the leadership of the hydrology section in its quest to foster scientific innovation, rigor and interdisciplinary focus on global issues. I have been an active member of the AGU since 2005, a member of two Technical Committees, and organizer (chair and co-chair) of eight different sessions. I have not run for any position before, so I am not controlled or beholden to special interests. I will be an independent democratic voice working closely with our Section President, Technical Committee chairs and AGU leadership, and will be there for all our Section members and non-members regardless of their personal philosophy, ethnic background, religion, culture, economic status or citizenship. It will be a great honor to serve you. To learn more about me and my work, please go to: faculty.sites.uci.edu/jasper.

Worth its weight: Ten years of satellite hydrogeodesy with GRACE

Ben Zaitchik (Johns Hopkins University)
Matt Rodell (NASA/Goddard Space Flight Center)
John Bolten (NASA/Goddard Space Flight Center)

The twin satellites of the NASA/German Gravity Recovery and Climate Experiment (GRACE) mission were launched just over a decade ago, in March 2002. Since that time, they have flown in Low Earth Orbit, 220 kilometers apart from one another, recording continuous, highly precise measurements of their location and the distance between them using GPS and a microwave ranging system. These measurements can be used to derive geodetic maps of Earth’s gravitational field, since accelerations of the satellites relative to each other are influenced by the presence of gravitational anomalies. Changes in the gravitational field over time are associated with the movement of mass near Earth’s surface, and over GRACE observed timescales—weeks to years—the movement of water constitutes a significant and quantifiable portion of this signal (Tapley et al., 2004). In this way, GRACE provides hydrogeodetic information by relating the temporal variations of the Earth's gravitational field to changes in the hydrologic cycle. Careful analysis of the GRACE signal over land yields estimates of terrestrial water storage (TWS) anomalies, a quantity that includes changes in surface water, snow and ice, vegetation water, soil moisture, and groundwater.

For hydrologists, the GRACE-derived TWS anomaly is an unprecedented and exciting measurement. It has made it possible to quantify the mass balance of the Greenland and Antarctic ice sheets (Velicogna and Wahr, 2006) and to monitor glacier dynamics in critical hotspots including the Alaska coast (Luthcke et al., 2008), Patagonia (Chen et al., 2007), and Central Asia (Matsuo and Heki, 2010). When combined with independent estimates of soil moisture variability, GRACE-derived TWS anomaly estimates can be applied to quantify changes in groundwater in regions of intense irrigation, including Northern India (Rodell et al., 2009; Tiwari et al., 2009) and California (Famiglietti et al., 2011), providing unprecedented regional-scale estimates of groundwater depletion rates. In addition, GRACE observations of natural TWS variability can be used to constrain the basin-scale water balance, supporting improved estimates of evapotranspiration, atmospheric moisture convergence, and river runoff (Rodell et al., 2004; Swenson and Wahr, 2006; Syed et al., 2009).

These studies of trends and basin-scale variability constitute the core of GRACE-based hydrology to date. Recent work, however, has demonstrated that GRACE also has considerable potential to contribute to analysis and operational monitoring of transient hydrological extremes. The application of GRACE to monitoring extremes, such as flood risk and emerging drought, presents a number of technical challenges. For one, GRACE-derived TWS anomalies represent time averages over a period of 10 days to one month, which results in a temporally smoothed signal with some unavoidable data latency. In addition, GRACE observations are spatially coarse, with a smoothing radius on the order of 300km. While this is acceptable for many basin-scale applications, studies of localized conditions and extremes require that the GRACE signal be downscaled to a resolution relevant to the operational warning or management system. Several recent studies show that these limitations can be overcome through informed use of available GRACE data in combination with other satellite observations and modeling techniques.

Reager and Famiglietti (2009) present an example of such an application to flood risk. By combining GRACE observations of TWS anomaly with Global Precipitation Climatology Project (GPCP) rainfall estimates, they identified regions in which repeat values of maximum TWS systematically fall short of variable maxima in accumulated precipitation — i.e., no matter how much it rains beyond a certain threshold, TWS does not rise above a given value. The presence of these TWS "ceilings" is indicative of a saturation threshold in water storage (S_{max}), and it can be inferred that as a region approaches this ceiling, the likelihood of flooding increases. For any given month, then, an available storage deficit for month m ($S_{deficit,m}$) is calculated on the basis of the climatologically-defined maximum storage and the observed storage in the previous month: $S_{deficit,m} = S_{max} - S_{m-1}$. Flood potential for month m can then be estimated in near real-time by comparing incoming precipitation (P_m) to available storage: Flood Potential = $P_m - S_{deficit,m}$. Importantly, this estimate of flood potential relies on GRACE observations from the previous month, which means that it could be implemented for operational monitoring using standard monthly-average GRACE TWS products. In this way the method is able to utilize time-averaged GRACE observations to monitor evolving risk of flood in near-real time.

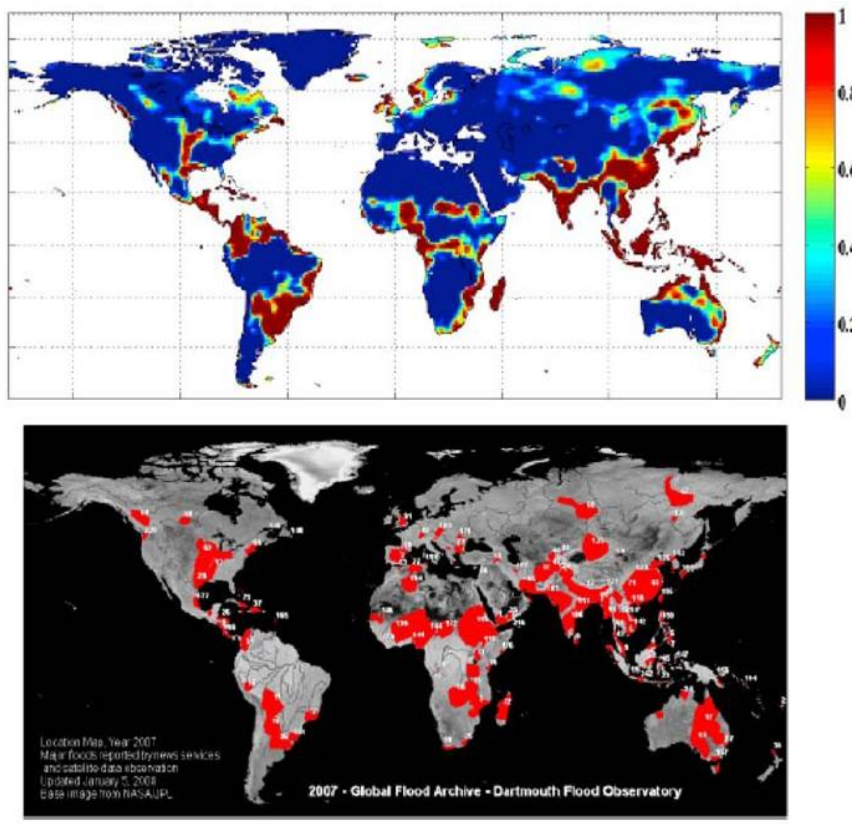

Figure 1: (top) GRACE-derived 2007 flood index maxima and (bottom) Dartmouth Flood Observatory reported floods in that year. Figure from (*Reager and Famiglietti*, 2009), reprinted with permission of the authors.

For cross-regional comparison, the flood potential can be normalized against historical maximum values, yielding a generalized GRACE-informed “flood index” can be defined to map flood potential globally. The resulting flood risk predictions can then be compared to independent observations of flood events (e.g., Figure 1).

In addition to improving estimates of flood risk, GRACE has received increased interest as a tool for drought monitoring. A unique aspect of GRACE with respect to hydrological remote sensing is its ability to sense changes in water stored in all levels of the soil column, including groundwater. Thus, GRACE provides the first ever potential to remotely monitor drought in a way that accounts for water deficit in deep soils and unconfined aquifers, information that has been lacking in operational drought products. Recognizing this potential, researchers from NASA’s Goddard Space Flight Center have worked with partners at the NOAA Climatic Data Center and the National Drought Mitigation Center (NDMC) of the University of Nebraska, Lincoln, to develop experimental GRACE-derived drought indices that complement the operational U.S. Drought Monitor drought severity product (e.g., Figure 2; also available in near-real time at http://drought.unl.edu/MonitoringTools/NASAGRACEDataAssimilation.aspx).

As described in a forthcoming paper by Houborg et al. (2012), the GRACE-informed drought indicators are derived using a GRACE Data Assimilation System (Zaitchik et al., 2008) that merges monthly GRACE observations of TWS anomalies with an advanced land surface model in order to generate estimates of groundwater, root zone, and near-surface soil moisture deficit that are informed both by model physics and by the GRACE observations. Because the data assimilation algorithm merges coarse, vertically integrated GRACE observations with relatively high resolution model parameters and meteorological data, and because the model can propagate GRACE anomalies forward in time, the system can be used to generate GRACE-informed estimates of storage deficits in near-real time at a finer spatial resolution than the GRACE observations. In this way, the GRACE assimilation drought monitor makes use of multiple data streams while overcoming the spatial resolution and data latency considerations that limit the direct application of GRACE to operational drought monitoring.

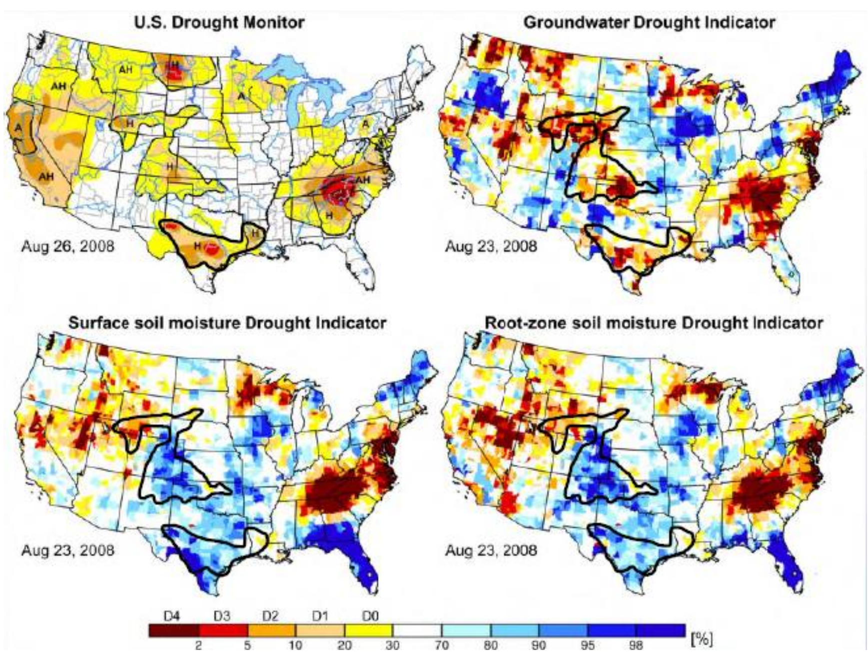

Figure 2: Drought severity as classified by the U.S. Drought Monitor operational system for a period in the summer of 2008, alongside GRACE-derived groundwater, surface soil moisture, and root-zone soil moisture drought indicators for the same period. Where some drought-affected areas (e.g., the Southeast) are evident in all indices, others (e.g., Texas and the western Great Plains) are captured only by the groundwater drought indicator. Methods described in *Houbourg et al.* (2012).

These recent flood and drought studies demonstrate two different ways in which coarse, time-averaged GRACE observations can be applied to monitor and potentially to predict hydrological extremes. As researchers continue to develop improved GRACE retrieval algorithms, data assimilation techniques, and hydrologically-informed interpretations of the GRACE record, we can anticipate broader and more refined methods for applying GRACE to the analysis of extreme hydrological events. This is an important line of application, since both flood risk and the emergence of severe drought depend on subsurface hydrological states that are extremely difficult to monitor using conventional measurement networks or, for that matter, satellite observations other than GRACE that detect only near-surface changes in water status.

Ten years into the mission, GRACE continues to inspire unique and innovative hydrological analyses. The promise of continued observations with the current GRACE system, along with the anticipated launches of the GRACE Follow On Mission in 2017 and GRACE II sometime in the next decade, is envisaged to result in improved and unanticipated hydrological applications of the satellite-based TWS observation.

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Climate forecasts and water management: Challenges and opportunities

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Considerable improvement in the skill of seasonal climate forecasts has been achieved over the last decade by exploiting slowly evolving boundary conditions such as sea surface temperatures (SSTs) in the tropical oceans (Goddard et al., 2003). Efforts linking these climate forecasts to antecedent land-surface conditions have also resulted in skillful streamflow forecasts (Koster et al., 2010). Furthermore, several studies have demonstrated the potential benefits of streamflow forecasts in improving water allocation through retrospective analyses (Voisin et al., 2006). Still, applications of seasonal to interannual climate forecasts are few in practice. We review herein the challenges in developing seasonal to interannual streamflow forecasts and discuss strategies for utilizing them to develop proactive water management plans.

Koster et al. (2010) showed that initial land surface conditions updated with climatological forcings can provide reliable streamflow forecasts, especially for snow-melt dominated basins. Retrospective and real-time climate forecasts show limited skill in predicting the observed precipitation – the critical variable for streamflow prediction – beyond about three months (Goddard et al., 2003). Recent studies have shown that climate forecasts developed from multiple climate models provide better-calibrated and more skillful precipitation forecasts (Rajagopalan et al., 2002). Sometimes statistical methods, using predictors identified from a diagnostic analysis of regional precipitation forcing in climate models, can provide even longer prediction horizons and higher skill for streamflow (Souza Filho and Lall, 2003). Despite this progress, numerous challenges and research questions remain in developing seasonal to interannual streamflow forecasts. We articulate the most pertinent ones here:

How best can streamflow forecasts be developed that are well calibrated and contain probabilistic information needed for water management (e.g., to support decisions for allocation for irrigation or other supply at 90% reliability)? What is the role of initial land surface conditions and data assimilation techniques in improving probabilistic information for seasonal streamflow forecasts?

Given the plethora of climate forecasts available from multiple General Circulation Models (GCMs) and multiple land surface models (LSMs), how best can systematic biases and model uncertainty be assessed and reduced? Invariably, different models appear to show skill in different regions, and the skill varies by the size of the region. Are these just spurious results born of multiple comparisons, or are some regions systematically more predictable independent of model choice? What aspects of data assimilation and initialization of models lead to differences and reduce systematic biases. How large do multi-model ensembles need to be to produce well-calibrated probabilistic forecasts? It is clear from past work that the uncertainty in climate forecasts typically dominates the uncertainty in hydrologic forecasts using climate forecasts. Given that, how much effort needs to be invested to improve land surface models, their data assimilation, and interaction with climate models to reduce total streamflow forecast uncertainty?

How do existing downscaling techniques translate large-scale climate information to the watershed scales required for streamflow forecasting? What are the best carriers (state variables) of probabilistic information available in the large-scale climate forecasts for probabilistic downscaling techniques?

How best can we utilize the skill in temperature, precipitation, wind and humidity forecasts for better prediction of streamflow and basin scale hydrology during the spring and summer? What is the additional gain in skill and lead-time in developing streamflow forecasts between snowmelt dominated basins over rainfall-runoff dominated basins?

How does groundwater storage modulate the skill in predicting seasonal streamflow forecasts? Why does the skill in predicting streamflow forecasts differ substantially for two adjacent basins even though there is similar skill in predicting precipitation and temperature for both basins?

Is there a higher/lower potential for predicting extreme hydroclimatic conditions (peak flow, drought severity and duration) than for routine forecasting? How can one separate the skills for such events, recognizing that extremes may require a significant reorganization of the atmospheric flow regimes and hence may be more predictable?

While many studies have already attempted to answer these questions, a comprehensive understanding that could lead to development of probabilistic streamflow forecasts that systematically reduce uncertainties in inputs, initial land surface conditions and LSMs is still lacking. Developing probabilistic streamflow forecasts that are well calibrated is critical for water managers and stakeholders to translate uncertainties in inflow forecasts to appropriate risk related to the specific water use.

Retrospective analyses on the utility of climate forecasts show that short-term water allocation policies developed using seasonal to interannual streamflow forecasts perform better than the climatology-based allocation (Sankarasubramanian et al., 2009). We discuss here various critical points that have been understood based on retrospective analyses over various reservoir systems.

Challenges in utilizing streamflow forecasts primarily arise from the need for probabilistic representations. For instance, forecast producers typically express the forecasts in the form of an ensemble, whereas forecast consumers – water managers and reservoir operators – have difficulty interpreting such products (Pagano et al., 2002). Traditionally, reservoir operation rule curves were developed based on observed flows over the entire period to address situations with potential shortages/spill. It is unclear to the operator whether there is much to be gained in modifying the fixed rule curve given that the inflow forecast has only marginal skill. Thus, a proactive change in the operational policy contingent on the probabilistic forecast could expose the manager to additional risk relative to the current status-quo operation (Pagano et al., 2002).

There is recognition that innovation in the water system operation and policy setting may be needed to facilitate the use of probabilistic forecasts. Sankarasubramanian et al. (2009) suggested a risk management framework for making the probabilistic inflow forecasts useful. Under this framework, the amount of water that can be supplied with a specified reliability to a certain user group could be estimated. Given heterogeneous users, the desired reliability and the value assigned to a certain quantity of water over the upcoming season will also vary by user class. Since the reliability of each contract has been estimated as part of the allocation process, the contract is also potentially insurable. The electrical utility industry offers option contracts or futures contracts of varying degrees of sophistication. There are also derivatives and other risk hedging instruments. These ideas are starting to enter the water management discussion as well, and their thoughtful development could provide a new mechanism for the application of probabilistic water supply and demand forecasts.

For streamflow forecasts to be beneficial over climatology-based allocation, initial storages in the reservoir should constrain the demand over the forecasting period. Otherwise, all the users are guaranteed of 100% reliability in allocation. Given that many major reservoir systems hold water to cover demand for more than one season, which is in general longer than the period for which the skillful streamflow forecasts are available, there is really no incentive for water managers to implement forecast-based proactive strategies. However, even under these conditions, one could use a probabilistic constraint on the end-of-the-season target storage for developing proactive management strategies (Sankarasubramanian et al., 2009). These will be perceived as more aggressive than the strategies that allocate only existing reservoir contents and consider a target end of period storage. However, in reality they can be a fool's gamble if the upcoming season turns out to be anomalously wet (spill) or dry (shortage). If the anomalous extreme is predicted as part of the probabilistic forecast, then there is some potential for more intelligent and lower risk allocation, and if it can be demonstrated that the forecast is well calibrated historically, then the reliability of the allocation can be evaluated, enabling potential insurance of the allocation policy and forecast use. Constraining the end-of-the-season storage in the allocation model provides useful information in capturing the shift in probabilities in the inflow forecasts and accordingly suggests restrictions (release additional water) during below-normal (above-normal) inflow years (Golembesky et al., 2009).

Given that multimodel inflow forecasts reduce false alarms and missed targets (Devineni and Sankarasubramanian, 2010), application of multimodel forecasts for water management promotes identification of relevant proactive strategies such as pre-season restrictions during dry years (Golembesky et al., 2009). Since the multimodel forecasts are also better calibrated with reduced model uncertainty, the confidence in using streamflow forecasts for potential applications also improves.

Forecasts are more beneficial for systems with low storage/demand ratio (Figure 1; Sankarasubramanian et al., 2009). Maurer and Lettenmaier (2004) also showed similar findings with forecasts being more beneficial for systems with low storage-to-inflow ratios. For systems that can hold multiple years of annual demand, the long-term benefits even under perfect forecasts is relatively small. This is primarily because the initial storages do not constrain the demand over the forecast period resulting in no difference in allocation between forecasts and climatology. On

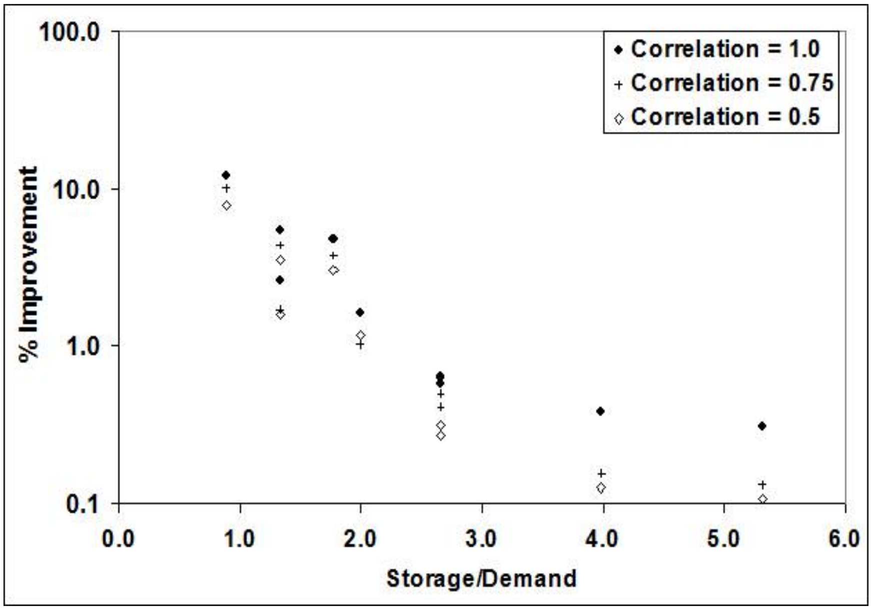

Figure 1: Utility of streamflow forecasts in improving water allocation for different reservoir storage-to-demand ratios and forecast skills (correlations). The nominal system (storage-to-demand ratio 5.32) was the Oros Reservoir system in Northeast Brazil. The % improvement is the average difference in annual yield for three different uses relative to climatological forcings over a period of 47 years. For additional details, see Sankarasubramanian et al. (2009).

the other hand, for basins with low storage-to-demand ratio, initial storage is expected to constrain the allocation particularly in extreme years. Thus, forecasts even with marginal skill could suggest substantial differences in allocation compared to climatology-based allocation.

It is also common that arid basins have over-year storage systems, since the interannual variability in streamflow increases with increase in basin aridity. For instance, humid basins in the eastern U.S. have low values of within-year system storage due to their smaller interannual variability. However, the utility of forecasts over climatology is dependent on both storage and the annual demand that the system is expected to supply. To summarize, forecasts are more beneficial for systems with low storage-to-demand ratio with multiple users constraining the allocation process.

From a technical perspective, we expect that work on improving climate informed streamflow forecasts will continue, and the identification of regional limits to predictability at different lead times will be established. The question is whether such information can be utilized for resource allocation in the current operating models, or whether innovations in instruments for allocation, such as options, derivatives and insurance are needed. The latter recommendations are likely to be situation dependent, both in terms of the instrument's effectiveness and in its manner of implementation; however, we expect that such strategies will be an integral part of managing water systems under uncertain nonstationarity.

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Managing water for environmental and ecological purposes

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Water systems are typically managed for water supply volume, reliability, cost, economic net benefit, social equity, or other socio-economic objectives (see e.g., Loucks et al., 2005). When included, environmental or ecosystem services typically are considered as static constraints such as satisfying a minimum in-stream flow value (e.g. Vogel et al., 2007). We argue that society's sustainability push requires a new science and practice to manage water more flexibly and dynamically according to quantifiable environmental and ecological performance metrics that consider uncertainties.

A small but growing body of work (Cardwell et al., 1996; Higgins et al., 2011; Suen and Eheart, 2006) has quantified and embedded environmental and ecological performance metrics in systems models to recommend management actions to improve ecological responses along river reaches. In the coming years and decades, we believe that water management science and practice must consider linkages and feedbacks among water, ecology, and society, particularly links that include wetland systems. We must also address functional and conceptual uncertainties to construct and use environmental objectives, formulate multiple promising solutions rather than a single best (optimal) solutions, plus provide environmental managers with actionable recommendations to improve their systems. Here, we briefly highlight some recent progress and future challenges to improve systems modeling and environmental water management in the lower Bear River basin, Utah.

The Bear River is the U.S.'s largest river (in terms of mean annual flow) that discharges to an inland sea. It flows through 3 states from headwaters in the Uinta Mountains, Utah to an outlet at the Great Salt Lake (GSL; Figure 1). Along the way, the river supplies important riparian and wetland areas, municipal, agricultural, hydropower, and recreational water users, including, at the river's terminus, 115 square miles of marsh, open water, uplands, and playa mudflats within the Bear River Migratory Bird Refuge, Utah (hereafter, the Refuge) that comprise the largest GSL freshwater

Figure 1: Location of the Bear River Migratory Bird Refuge and other important riparian, urban, and agricultural water uses within the Bear River basin.

ecosystem complex plus globally significant resting and breeding areas for migratory birds that follow the North American Pacific and Central Flyways. Within the Refuge, U.S. Fish and Wildlife Service managers use dikes, weirs, and canals to manually regulate Bear River water into 25 wetland units and create a diversity of wetland, aquatic macro invertebrate, and aquatic plant community types that mimic a well-functioning freshwater ecosystem with multiple birding, hunting, and other wetland services (Olson, 2009). Yet Refuge and upstream environmental managers are concerned about new in- and out-of-basin withdrawals for growing northern Utah municipalities plus the spread of the non-native, invasive Common Reed (*Phragmites austraulis*; hereafter *Phragmites*). Managers want to know how changes will impact wetland and riparian areas and how they can secure and better allocate scarce water to respond (Endter-Wada et al., 2009; Sehlke and Jacobson, 2005).

Since 2009, we have undertaken participatory modeling with Refuge managers and, as a result, developed a systems model that recommends water allocations among wetland units and *Phragmites* control actions to improve wetland habitat for priority bird species. Model recommendations are subject to constraints such as water availability, spatial connectivity of wetland units and canals (Figure 2), hydraulic infrastructure capacities, financial and time budgets to manage vegetation and water, and vegetation responses to control actions.

The model seeks to maximize wetland habitat performance, which is quantified using individual and aggregate metrics. The first individual metrics are habitat suitability indices (HSIs) that represent the capacity of a water depth or vegetation cover habitat attribute to support selected bird species (Figure 3). Suitability ranges from 0 (poor) to 1 (excellent) habitat quality. For example, birds like American Avocet (*Recurvirostra americana*) prefer water depths between 0.4 and 0.6 m, implying HSI values near 1 for that range of water depths. We combine the water depth and vegetation coverage HSIs, weight by species, month, and the wetted surface area to create the second aggregate indicator defined as the weighted usable area for wetlands (WUAW). The WUAW represents the available surface area that provides suitable hydrological and ecological conditions for priority bird species.

To date, we have run the Refuge systems model for numerous scenarios representing variations of water availability, vegetation response, and the financial and time budgets available to control invasive vegetation and regulate water. We have also simulated historical water allocations and resulting WUAW performance and compared the observations to model recommendations. Our collaborating Refuge partners have provided and verified numerous model inputs and expressed great excitement for, and interesting interpretations of the results. For example, in early model runs, we neglected to include a constraint limiting the time available for managers to adjust water levels in wetland units. As a result, the model sought to frequently change water levels within wetland units over a year and our Refuge partners pointed out that they don't have the staff to manually open/close gates and weirs so frequently. However, they said the results quantify the *additional* ecological benefits of installing an automated, remote-operated water control system. We also systematically varied the annual water volume available to the Refuge and found that wetlands performance

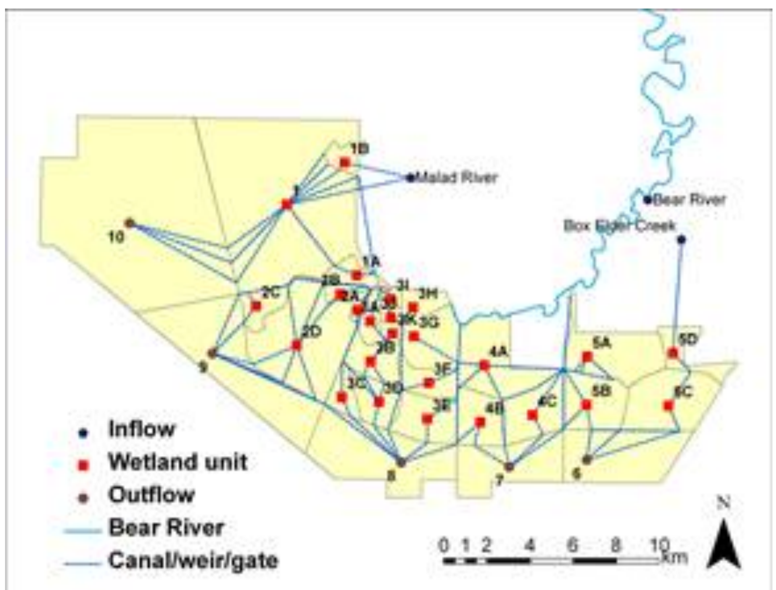

Figure 2: Schematic of the systems model for the Bear River Migratory Bird Refuge, Utah that shows three water inflow locations, 25 actively managed wetland units, conveyance links, and 5 outflows to the Great Salt Lake.

critically drops when this volume falls below the Refuge's existing water right of approximately 1,000 cfs. This result suggests the Refuge should be very concerned about new, upstream abstractions.

We are now pairing classified, remotely-sensed images of Refuge vegetation coverage dating back to 1992 with historical water levels to develop improved water-plant response relationships to embed in the model. Additionally, we are developing a streamlined model user interface so that Refuge managers can use the model in their annual planning.

The Refuge systems model treats as exogenous the cumulative effects of all upstream activities in the Bear River, such as the water available to the Refuge. Thus, we are also now embedding the Refuge model in a larger systems model for the lower Bear River that includes upstream environmental and ecological areas of significance, municipal and agricultural uses, reservoirs, diversions, and return flows. This larger-scale model will include more species, habitat attributes, locations, and alternative water uses and will be used to identify tradeoffs among them. The model will also identify promising reservoir releases, diversions, trades, exchanges, and coordinated water management actions that benefit one or multiple users. To do this, we will again quantify environmental and ecological performance metrics for wetland and riparian areas of interest, embed these metrics in an existing water supply model for the lower Bear, and explore the effects of uncertainties in performance indicators on recommended water management regimes. We will also identify and allow managers to interactively explore the region of near-optimal solutions that perform within a specified tolerance of the optimal objective function value.

Why near optimal? Because modeled "best" or "optimal" solutions are often sub-optimal when uncertainties and un-modeled issues persist (Brill et al., 1982; Chang et al., 1982). Generating the near-optimal solutions allows a decision maker to select an appropriate solution using criteria not quantified in the model. Prior work (Burton et al., 1987; Matheiss and Rubin, 1980) found computational difficulties to characterizing the near-optimal regions of large linear problems, but twenty-five years later we have developed and are applying new scalable algorithms and parallel coordinate plotting techniques to identify and visualize these regions (Rosenberg, 2012) and are now extending the techniques to non-linear problems. These techniques will likely find broad applicability in environmental water and other management sciences.

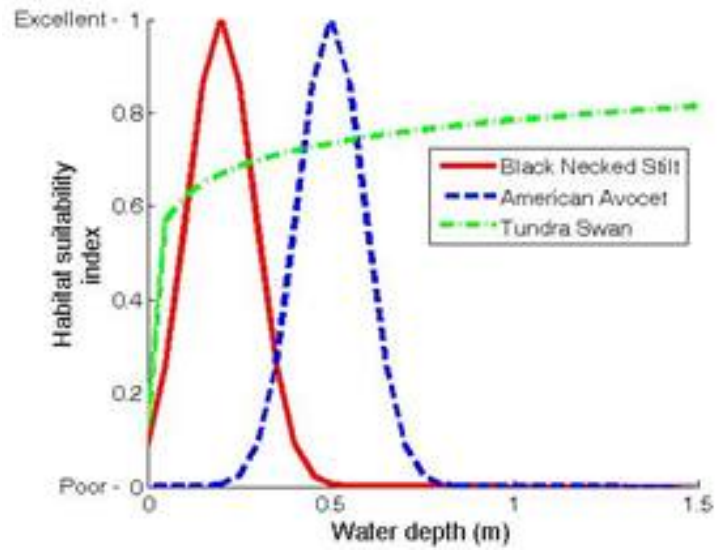

Figure 3: Habitat suitability index curves show water depth preferences for three priority bird species at the Bear River Migratory Bird Refuge, Utah that the systems model seeks to achieve.

Our work in the Bear River highlights participatory and dynamic approaches to manage water for environmental and ecological purposes. We must manage according to quantifiable environmental and ecological performance metrics rather than meet in-stream flow requirements. We must involve managers and stakeholders from the beginning in problem identification and data collection through interpretation and application of results. We must also consider the effects of uncertainties in our performance metrics and present a wider region of near-optimal or promising solutions from which managers can choose. Together, these approaches will help advance the science and practice of sustainable water management.

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Integrated hydrologic ground validation for NASA's Precipitation Measurement Missions

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As NASA approaches the launch dates for upcoming hydrology-related missions, such as the Global Precipitation Measurement (GPM) mission (http://pmm.nasa.gov/GPM; scheduled launch February, 2014) and the Soil Moisture Active/Passive (SMAP) mission (http://smap.jpl.nasa.gov; scheduled launch October, 2014), several field campaigns are planned that will be of interest to the hydrology community. This short article summarizes proposed hydrology-related ground-validation (GV) activities for GPM.

GPM will represent a major advance in the quantitative measurement of precipitation from space. In contrast to its predecessor mission, the Tropical Rainfall Measurement Mission (TRMM; http://pmm.nasa.gov/TRMM), a key motivation for GPM is to support land hydrology. Specifically, one of the five scientific objectives for GPM is to *improve hydrological modeling and prediction*, including the advancement of skill for modeling and predicting high-impact hazards such as floods, droughts, landslides and land-falling hurricanes. Indeed, this particular objective drives the need for structured *hydrologic analysis and assessments* of GPM products. Accordingly, GPM GV plans recognize and include the need for an integrated hydrologic GV component.

The rationale for integrated hydrologic GV (hereafter Hydro-GV) recognizes that hydrologic analysis is not a passive receiver of the satellite products, but rather can be an integral part of improving the products to meet the hydrologic

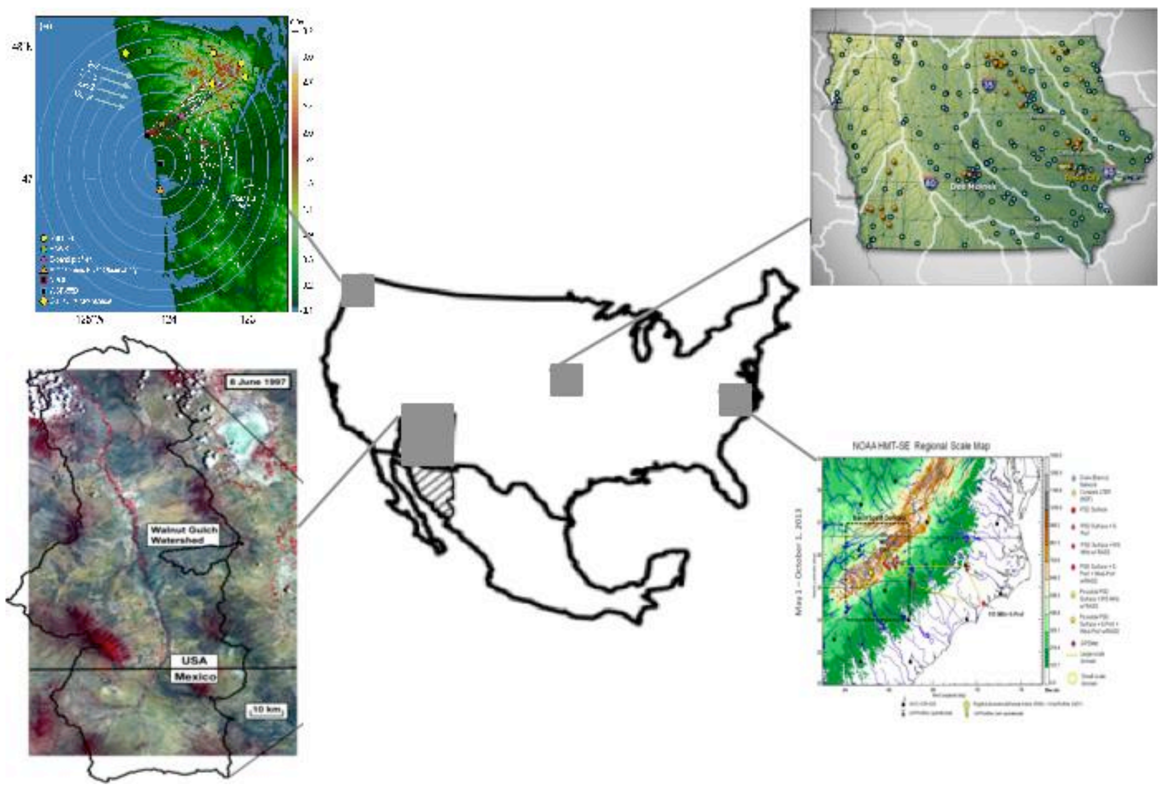

Figure 1: Sites proposed for Hydro-GV activities and field campaigns. Top left: Rain-snow transitions and flooding on the Olympic Peninsula (e.g. Quinault and Chehalis Basins); Top right: Large-scale flood studies focused in Iowa; Lower Left: Hydrologic studies in arid-monsoon regimes of the San Pedro/Walnut Gulch Watersheds of Arizona; Bottom Right: Orographic convection and flooding in the HMT-SE domain of North Carolina.

applications needs. Thus, the proposed Hydro-GV plan includes downscaling of precipitation products, merging of products for increased resolution and accuracy, and contributions and feedback to the physical retrieval teams. The overarching objectives of Hydro-GV are to improve the accuracy and resolution of satellite precipitation products and assess the performance of these products in hydrologic and water resources applications, including characterization of observational and modeling uncertainty. More specific objectives include:

- Characterization of uncertainties in satellite and ground-based (radar, dense gauge networks) rainfall estimates over a broad range of space/time scales
- Characterization of uncertainties in hydrologic models and understanding propagation of input uncertainties into model forecasts
- Assessing performance of satellite rainfall products in hydrologic applications over a range of space-time scales
- Using data from synergistic missions (e.g. SMAP) to refine hydrologic model parameters and improve predictions driven by GPM input data.

One requirement of the Hydro-GV activities will be that they span a set of hydro-climate regimes and times that capture high-impact hydrological hazards and related physical retrieval challenges. Examples of regimes considered by the Hydrology Working Group include:

- Large Scale Floods;
- Landfalling Hurricanes;
- Orographically-Enhanced Convection;
- Warm-Season Convection; and
- Snow/Rain Transition.

The PMM Hydrology Working Group has considered regime-dependent errors and outstanding science issues based on substantial experience with the current TRMM-era products, models and techniques. Accordingly, Hydro-GV activities will proceed along two major lines. First Hydro-GV will establish pre-launch baselines nationally and globally. Second, Hydro-GV will implement field campaigns that a) target hydro-climatologically diverse areas/regimes and b) leverage existing/planned research or operational measurements being made within these areas/regimes.

Relative to the first Hydro-GV emphasis, pre-launch baselines for evaluating both quantitative precipitation estimation (QPE) and hydrological forecasting skill will make use of current-generation satellite, model and combined radar-gauge precipitation products as inputs for long-term simulations from hydrological and land surface models nationally and globally. As new QPE products are released, both pre- and post-launch, the initial baseline will be re-evaluated. This work could be an extension of the existing TRMM global flood and landslide monitoring systems (Hong et al., 2007), the Global Land Data Assimilation System (GLDAS; Rodell et al., 2004), and national network GV activities, such as the North American Land Data Assimilation System (NLDAS; Mitchell et al., 2004). These activities will allow us to establish routine benchmarking of hydrologic prediction skill for PMM, and more focused integrated GV field efforts targeted to the aforementioned regimes of interest (second Hydro-GV emphasis).

Integrated field efforts at several Hydro-GV sites are expected to further advance satellite-based QPE and our understanding of uncertainties and the propagation of errors into various aspects of hydrologic prediction. While implementation of the proposed Hydro-GV field measurements is still under discussion, the basic plan is to leverage existing observational networks while deploying additional gap-filling observational assets via the GPM GV program (Table 1). The targets of each field campaign include a mix of physical and integrated hydrological validation objectives specific to the four aforementioned regime-types found at the sites shown in Fig. 1.

Table 1: GPM GV resources that could be requested for Hydro-GV field campaigns.

Observational Objective	Description
Radar Reflectivity, Precipitation Rates	NPOL Radar: S-band, dual-polarization, 0.9° beam, transportable
Radar Reflectivity, Precipitation Rates	D3R Radar dual-frequency (Ka-Ku), dual-polarization, transportable
Precipitation Rates / DSD	~25 Disdrometers (5 2DVD, 20 Parsivel-2)
Precipitation Rates / DSD	3 Micro Rain Radar II
Precipitation Rates / DSD	50 MetOne TB rain gauges
Precipitation Rates / DSD	7 TPS-3100 All weather hot-plate sensors
Precipitation Rates / DSD	9 OTT Pluvio^2 weighing gauges

- iFLOODS: Large Scale Flood: Iowa, May-July, 2013
- HMT-SE: Orographically-Enhanced Convection: HydroMeteorological Testbed (HMT)-Southeast (joint with NOAA), North Carolina, May-July 2014
- SMAPex: Arid Monsoon: San Pedro-Walnut Gulch, Arizona, Jul-Aug., 2015 (dependant on SMAP validation plans).
- OLYMPEX: Snow-Rain transition/ Orographic/Flooding: western Olympic Peninsula, Washington, Nov-Dec. 2015.

In summary, the evolving plans for GPM Hydro-GV presents unique opportunities for integrating precipitation remote sensing algorithm development with large-scale field experiments designed to represent a range of hydro-climatological regimes across the continental U.S. The locations of these experiments remain tentative, along with the nature of specific field programs that might be conducted at these sites, but are expected to become more concrete over the next year. The PMM Hydrology working group (which the author chairs) welcomes community input and collaboration in meeting GPM science objectives related to hydrology.

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The perception of scale in surface water and groundwater hydrology

Tom Gleeson (McGill University)
Dawn Paszkowski (University of British Columbia)

The discipline of hydrology has a long history of research in the practical and theoretical aspects of scaling and scale issues, but little effort has focused on hydrologists' perception of the scale terms. Scale terms are often poorly defined or not defined at all. What exactly do hydrologists mean when they use the terms 'pore scale', 'watershed scale' or 'large scale'? Advancing and applying hydrologic research requires clear communication both within the discipline and with a broader audience.

Practical restrictions that constrain hydrologists to a finite number of samples leads to the necessity of observing hydrologic processes, which naturally vary over many orders of magnitude, over certain, specific *observation scale*s (Blöschl and Sivapalan, 1995). Dooge (1997) suggested nine different observational scale terms from molecular (10^{-10} m) to global (10^{8} m) which is the only previous attempt to suggest an observational scale nomenclature for the hydrologic community, to our best knowledge. The observational scales of hydrology have not previously been quantitatively or qualitatively examined.

Our objective was to examine the perception of scale in the hydrologic community using voluntary one-page surveys distributed at two professional meetings. Survey responses were collected at the GSA Annual Meeting in Denver, October 2010 during the Hydrogeology Section luncheon, as well as at the AGU Fall Meeting in San Francisco, December 2010 during the Hydrology Section luncheon. Participants were asked to specify the length-scale they associate with various scale terms, in addition to the perceived meaningfulness of the terms. The data on meaningfulness is not included here for purposes of brevity.

Respondents ($n = 147$) were categorized following the AGU Hydrology Section Technical Committees: surface water hydrologists ($n = 30$), groundwater hydrologists ($n = 76$) and other and undeclared ($n = 41$). All participants from GSA were categorized as groundwater hydrologists, while participants from the AGU Hydrology Section luncheon were categorized based on their response to an optional question requesting they identify their subfield or research area.

One simple first observation is that the science and practice of hydrology is concerned with a huge range of scales. The 19 orders of magnitude (10^{-9} m to 10^{10} m) identified by the groundwater and surface water hydrologists surveyed is consistent with the 18 order of magnitude (10^{-10} m to 10^{8} m) range from Dooge (1997).

There is reasonable convergence between surface water and groundwater hydrologists on the perception of many scale terms (Figure 1). The mean value for surface water hydrologists falls within a single standard deviation of the mean value for groundwater hydrologists, and vice versa, for all scale terms except large scale and watershed scale. However, watershed scale for groundwater hydrologists should be interpreted tentatively because this term was not included in the survey at

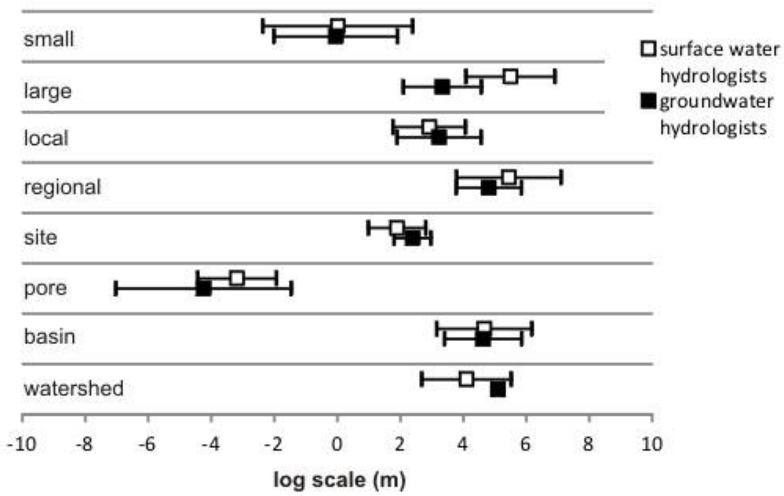

Figure 1: Perception of scale terms among surface water and groundwater hydrologists.

GSA so the number of respondents is small ($n = 13$).

Commonly agreed upon terms and their meaning within the hydrology field would facilitate intra-disciplinary research, as well as communication with other disciplines and the general public. We echo other researchers, who have called for more strict definition of scale terminology (e.g. Janauer, 2000) and for more explicit accounting for scale as a variable in analysis (e.g. *Marceau*, 1999).

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Water is everywhere

Sasha Richey (University of California Irvine)

"The water in my tap is clean, at least here in the United States." "Desalination will provide infinite and cheap freshwater into the future." "Bottled water is more regulated than tap water." "Recycled sewage water is unhealthy and gross." "There is a water crisis somewhere else, but not here." These are just some of the myths that *Last Call at the Oasis* tries to debunk. *Last Call at the Oasis* is a new water documentary made by Participant Media, the same company that produced *An Inconvenient Truth*, *Food Inc.*, *Waiting for Superman*, and *The Help*. UC Irvine Professor Jay Famiglietti (my advisor), Pacific Institute President Peter Gleick, UC Berkeley biology Professor Tyrone Hayes, University of Arizona law Professor Robert Glennon, and environmental activists Erin Brockovich and Lynn Henning are some of the "characters" brought together in interweaving stories that present the many complexities surrounding sustainable water management.

Academy Award-winning director, Jessica Yu (*Breathing Lessons: The Life and Work of Mark O'Brien*), and Academy Award-nominated producer, Elise Pearlstein (*Food Inc.)* tackle the challenge of bringing water issues to the forefront. Fresh water isn't everywhere, and where it does exist, we often take it for granted, contaminate it, and generally use it as an infinite resource. AGU Hydrology members already know this, right? Maybe, but conveying these truths to the public while retaining scientific accuracy about the ways we use and abuse water is a challenge. I personally couldn't have told the stories connecting human population and economic growth challenges with drought, climate change, or transboundary water resources cooperation, or described the psychological issues of disgust surrounding drinking recycled, "toilet to tap", water. Not only have Yu and Pearlstein (with help on that last issue from actor/comedian Jack Black) successfully woven together these stories in *Last Call at the Oasis*, they have managed to make the importance of global water issues relatable to today's average American. Although we hydrologists often discuss water as a sustainability or even security issue, this film allows us to share these challenges and our research with a broad audience.

A disconnect exists between academics, policy- and decision-makers, and the public. In general, many scientists claim science-based decision-making is lacking; policy-makers claim scientists speak a different language. A translator or "boundary organization" can create improved communication pathways. *Last Call at the Oasis* serves this role. The dramatic consequences of atrazine, studied by Tyrone Hayes, is visually demonstrated and described in language that is understandable to a non-biologist. The incredible value of NASA's Gravity Recovery and Climate Experiment (GRACE) satellite mission, which shows changes in water storage on a large scale not limited by political boundaries, was presented with animations of the data over certain regions while being narrated by Jay Famiglietti. Pat Mulroy, General Manager of the Southern Nevada Water District, described the management challenges related to Lake Mead and the fact that Hoover Dam faces the real possibility of being unable to produce power in four years. At the same time, the scientific issues related to Lake Mead were illustrated in great visuals and narrations by Tim Barnett from Scripps.

Reviews of *Last Call at the Oasis* have been staggeringly positive. The Los Angeles Times said, "Yu has made a film that is as visually arresting as it is smart." The New York Times also backed Yu saying, "Ms. Yu… wraps a lot of bad news into a slick, informative, fast-moving package." However, despite positive film reviews, ticket sales have been underwhelming. *Last Call at the Oasis* was released in Los Angeles and New York on May 4, 2012, only to battle the super-human ticket sales of *The Avengers*. It was released a week later in Berkeley, San Francisco, Irvine, Las Vegas, and Washington D.C., at which point it had already been pulled from New York due to low ticket sales. Why have ticket sales been low despite rave reviews? There seem to be two main reasons: 1) as with most documentaries, there has been minimal publicity and advertising so very few people know about it, and 2) it is challenging to get people to see a movie that, while inspiring on the one hand, is quite daunting and can be viewed as a depressing, information-packed reality check.

So where does that leave us? That leaves *us*, the hydrology community, to continue taking the lead on communicating the importance of water to the world at whatever level or niche we engage with it. *Last Call at the Oasis* will continue to serve as a "boundary organization" to spread this message. It is now available to anyone to who wants to host a screening, at minimal cost, through an organization called Tugg (www.tugg.com).

Tugg provides an avenue to bring any film in their library, including *Last Call at the Oasis*, to your community. All you have to do is pick a date and theater in your area where you would like to show *Last Call at the Oasis* and guarantee that you can get enough people to buy tickets. Tugg works with the theater you choose to host the screening, and determines the minimum number of tickets you must sell in order to show *Last Call at the Oasis* there. All you have to do as the organizer is to ensure that the minimum number of people buy tickets beforehand. If you don't reach the minimum ticket sales, no one gets charged and you can try again. Otherwise, the only cost of bringing *Last Call at the Oasis* to your community is the cost of tickets, and Tugg will ensure that the film is screened at the time and location of your choosing. *Last Call at the Oasis* will be available through Tugg for 18 months.

The future of water is in our hands, and in our ability to convince the world that sustainable, science-based management is needed now. I hope you consider hosting or attending a *Last Call at the Oasis* event through Tugg, or seeing the film through another venue.

2011 Outstanding Student Paper Award Winners			
Awardee	**Paper Title**	**Institution**	**Advisor**
Patrick Broxton	Combining KINEROS with SM-hsB for Flash Flood Predictions in Small to Medium Sized Watersheds	University of Arizona	Peter Troch
Jennifer Druhan	Observing the coupled behavior of geochemistry and flow path evolution during bioreduction using clinical nuclear imaging tomography	Univ. of California, Berkeley	Don DePaolo
Mohammad Ebtehaj	Sparse Downscaling and Adaptive Fusion of Multi-sensor Precipitation	University of Minnesota	Efi Foufoula-Georgiou
Nicholas Engdahl	Direct upscaling of kinetically controlled reactive transport with mobile-immobile mass transfer	University of California, Davis	Graham Fogg
Nicholas Haas	Analysis of Daily-Peaking and Run-of-River Dam Operations on Flow Variability Metrics Considering Subdaily to Seasonal Timescales	State University of New York College of Environmental Science and Forestry	Ben O'Connor and Ted Endreny
Kevin Hanley	Understanding controls on dissolved organic carbon flux and lability in United States watersheds	University of New Hampshire	Wilfred Wollheim and Joseph Salisbury
Keith Harding	Modeling the Current and Future Impacts of Irrigation on Great Plains Precipitation	University of Minnesota	Peter Snyder
Peter Kang	Insights about the Origin of Anomalous Transport through Fractured Media: Modeling and Observations from a Field Test in Fractured Granite	Massachusetts Insitute of Technology	Ruben Juanes
Maria Klepikova	A methodology for using borehole temperature-depth profiles under ambient, single and cross-borehole pumping conditions to estimate fracture hydraulic properties	Geosciences Rennes	Tanguy Le Borgne and Olivier Bour
John Leeman	Experimental Results of Hydrate Reservoir Destabilization Through Heating	University of Oklahoma	Megan Elwood-Madden
Jingjing Li	A hybrid framework for verification of satellite precipitation products	University of California, Irvine	Soroosh Sorooshian
Maimuna Majumder	Water Quality vs. Sanitation Accessibility: What is the most effective intervention point for preventing cholera in Dhaka, Bangladesh?	Tufts University	David Gute

2011 Outstanding Student Paper Award Winners			
Awardee	**Paper Title**	**Institution**	**Advisor**
Nasrin Nasrollahi	Application of CloudSat cloud classification maps and MODIS multi-spectral satellite imagery in identifying false rain from satellite images	University of California, Irvine	Soroosh Sorooshian
Michael Natter	Fate and Transport of Organic Contaminants in Coastal Marsh Sediments Resulting from the 2010 Gulf Oil Spill	Auburn University	Ming-Kuo Lee
Casey Nixon	Variations in topology and strain within strike-slip fault networks	University of Southampton	Jon Bull and Dave Sanderson
Yadu Pokhrel	Modeling Irrigation Pumping and Groundwater Depletion in the High Plains Aquifer, USA	University of Tokyo	Taikan Oki
Andrew Racz	Modeling the spatial and temporal dynamics of infiltration during managed aquifer recharge	University of California, Santa Cruz	Andrew Fisher
Gabriel Rau	Is thermal dispersivity significant for the use of heat as a tracer?	University of New South Wales	Martin Andersen and Ian Acworth
Wendy Robertson	Nitrate in Arid Basin Groundwater: How Historical Trends in Water Quality, Pumping Practices, and Land Use Inform our Understanding of Flow in these Systems	University of Texas at Austin	John Sharp
Dawn Roberts-Semple	Seasonal characteristics of gas-phase air pollutants: implications for public health in northeastern New Jersey	Rutgers University	Yuan Gao
Marilyn Roland	Modeling Karst Ecosystem-Atmosphere CO2 Exchange: The Importance of Ventilation for Carbonate Geochemistry	University of Antwerp	Ivan Janssens
Philip Saksa	Forest management for water: a hydro-ecological modeling exercise of headwater catchments in the mixed-conifer belt of the Sierra Nevada	University of California, Merced	Roger Bales
Keith Sawicz	Top Down Modeling and Catchment Classification: Insight into hydrologic processes/function and hydrologic similarity	The Pennsylvania State University	Thorsten Wagener
Marie Scholer	Comparing time-lapse GPR data collected under natural and forced infiltration conditions to estimate unsaturated soil hydraulic properties	University of Lausanne	Klaus Holliger and James Irving
William Smith	Global bioenergy capacity as constrained by observed biospheric productivity rates	University of Montana	Steve Running

2011 Outstanding Student Paper Award Winners			
Awardee	**Paper Title**	**Institution**	**Advisor**
Benjamin Tutolo	An Assessment of Thermodynamic Database Effects on Reactive Transport Models' Predictions of Permeability Fields: Insights from CO2/Brine Experiments	University of Minnesota	Martin Saar
Rohit Warrier	Mixing of deep basinal brines and glacial meltwater inferred from major ion chemistry, stable isotopes and noble gases in the Saginaw aquifer, Michigan	University of Michigan	Clara Castro
Yipeng Zhang	Multi-Layer, Sharp-Interface Models of Pore Pressure Buildup within the Illinois Basin due to Basin-Wide CO_2 Injection	New Mexico Institute of Mining and Technology	Mark Person
Tongtiegang Zhao	Incorporate Hydrologic Forecast for Real-Time Reservoir Operations	Tsinghua University	Ximing Cai
Margaret Zimmer	Fine scale variations of surface and ground water chemistry in an ephemeral to perennial drainage network in the Hubbard Brook Experimental Forest, NH, USA	Syracuse University	Laura Lautz

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