45 BEACON

LETTER FROM HEADQUARTERS

SHARING RESEARCH PUBLICATIONS

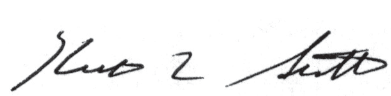
Several social networking sites for scientists and researchers have been launched in the past few years. One that has gained popularity, and that I will highlight specifically as an example of all such sites, is ResearchGate.com. Many in our community (including me) have joined ResearchGate, and it seems that number is growing relatively quickly.

A key feature of the site is the opportunity to share one's publications with other researchers. ResearchGate makes it very easy to upload the full text of articles. Authors might assume that ResearchGate would not offer to upload the full text at the click of a button if doing so would violate a publisher's copyright, but while there is text on the site encouraging authors to follow the publisher's copyright policies, the ResearchGate system does nothing to enforce compliance with publisher policies. I encourage all authors to carefully check the copyright policies for their published work before allowing their papers to be uploaded to sites such as ResearchGate in order to avoid violating the copyright on those papers. AMS copyright policies[1] do not allow authors to upload copies of papers published in *BAMS* or AMS journals to non-AMS servers, with the exception of specific institutional repositories that meet the criteria outlined in the AMS Copyright Policies.

The fact that AMS copyright policies do not allow one to upload the full text of AMS published articles does not mean that members of the community are prohibited from participating fully in scientific social networking sites such as ResearchGate. Such sites can still list an author's publications, including full citations, abstract, and links to the full text residing on the AMS servers. Further, in the case of ResearchGate, it is easy for others to request the full text from the author with a single click—allowing the article to be shared fully and easily without violating copyright.

Most of the research that has been published in *BAMS* and AMS journals over the years is now freely available as open-access content, and most researchers have transparent access through their institution's subscriptions to the remaining fraction of recently published content that is not open-access. It is thus understandably easy for authors to forget that copyright protections still apply for all of the content. What is important to remember is that holding the copyright to a work allows AMS to act as a steward for that work for the long term—protecting the intellectual property of the author and ensuring that the definitive version of the work can remain identifiable, discoverable, and citable throughout whatever technological changes may occur. AMS copyright policies are intended to allow broad dissemination of works, while at the same time allowing AMS to fulfill its obligations to protect the integrity of the works it has published.

Being aware of copyright restrictions and working within the copyright policies established by each publisher will allow everyone in our community to take advantage of the social networking sites now available to the community to share research and establish meaningful connections with others.



Keith L. Seitter, CCM
Executive Director

[1] www2.ametsoc.org/ams/index.cfm/publications/authors/journal-and-bams-authors/author-resources/copyright-information/copyright-policy/

10 QUESTIONS WITH . . .

A new series of profiles celebrating AMS Certified Broadcast Meteorologists and Sealholders

Rich Johnson
Atlanta, Georgia

How has the field changed since you started? When I started we would receive weather information over teletypes and facsimile machines and post the paper copies on the weather wall. Today we have computerized graphics of nearly every forecast parameter and even in 3D!

What technology could you not live without? Radar and satellite imagery. I can't imagine forecasting tornadoes or hurricanes without those tools.

Who has been your biggest role model? This is an easy question. John Hope. He taught me how to forecast hurricanes. He was not only an excellent scientist but a very kind, godly man.

What is your ideal weather/climate? San Diego weather. Lots of sun with highs in the 70s and lows in the 50s. Although I wouldn't mind an occasional snowstorm or thunderstorm, too.

What is the best thing about what you do? I get to help people. I enjoy helping people learn about weather and stay safe during threatening conditions.

What's the biggest weather event you've reported on? There's too many to count. I would say being on the air as the backup hurricane expert just before landfall of Hurricane Andrew and Hurricane Katrina would be at the top.

How do you deal with criticism over forecasts that don't pan out? I try not to take it personally and learn from the mistake so I can make a better forecast next time.

What types of weather or weather phenomena do you get most excited about? As I suspect most meteorologists would say, severe weather—tornadoes, hurricanes, snow, and ice storms. There is an important distinction to make here, though. I would rather use a different word than "excited" because in my mind that means it's something that I'm hoping is going to happen.

What was the most important way to prepare you for this job? 1) Know the science. Constantly be looking at research and new tools to do the job better. 2) Critically review your broadcast tapes. Don't copy other successful broadcast meteorologists; instead be your own person. 3) Learn Spanish. More stations are looking for bilingual broadcasters. 4) Be a person of integrity and work hard. This will prepare you to be a good coworker.

What are the biggest meteorological challenges in your job? The numerical forecasts are always wrong. It is our job to know where the models perform the best and where they may fail. Even when we use all of the available data at our disposal, forecasts still may not work out.

Rich Johnson worked at The Weather Channel for 25 years. He received his CBM in 2006. For more information on AMS Certification Programs, go to www.ametsoc.org/amscert/index.html.

DOUG HAHN
Technical Editor

Before joining AMS as a technical editor (TE) in January 2013, Doug Hahn had planned on an early retirement from a career in the U.S. Air Force. But then he had a fortuitous lunch meeting with Ken Heideman, director of the AMS Publications Department. Ken happened to also be a friend and former colleague at the Air Force Geophysics Laboratory at Hanscom Air Force Base (AFB) in Massachusetts, as well as a fellow Penn State graduate.

"During one of our lunches I inquired if there were any positions at AMS publications available, knowing that I had more than a few years before I could really retire," Doug says. "When he told me there was an opening as a technical editor, I was very interested with the idea of becoming a TE as second career, especially since I would follow a few of my fellow AF laboratory colleagues who made the same move after retirement and inspired me to become a TE for the AMS journals."

Like many in the field, Doug's love of science began at a young age, when he would go on camping and hiking trips with his Boy Scout troop. That continued with family camping trips as a teenager traveling all around the U.S. northeast.

"I became interested in environmental science—and the weather in particular—with my middle-school science classes," Doug explains. "In high school I had a job with the local airport authority, where I was able to spend my breaks talking about the weather with the local National Weather Service meteorologists and about aviation weather with the local Federal Aviation Administration traffic controllers."

After high school, Doug attended Penn State as a meteorology major, where he became interested in computers and numerical weather prediction (NWP) in particular.

"I was able to tailor studies during my senior year to investigate atmospheric predictability based on Professor Edward Lorenz's famous *Journal of the Atmospheric Sciences* article 'Deterministic Nonperiodic Flow' that lead to a senior thesis for credit," Doug says.

After receiving his B.S. in meteorology in 1985, he accepted a job with the Air Force Geophysics Laboratory (AFGL) at Hanscom AFB. He remained with AFGL and its follow-on organizations until 2008, finally ending with the Air Force Research Laboratory. During his time with the laboratory, he completed graduate work at the Massachusetts Institute of Technology, where he studied using global models for climate prediction. In early 2008, Doug moved to the Air Force's Electronic Systems Center, where he was a program manager in the Weather Program Office until retirement in 2012.

"My background includes research in NWP, specifically with global forecast models, statistical cloud forecasting, boundary- and surface-layer parameterizations, and forecasting gravity waves and high-altitude turbulence using mesoscale models," Doug explains. "Having the knowledge in those fields has helped me immensely in my work as a technical editor."

Before leaving the Air Force, he led a $109-million program to upgrade the weather databases used by the Air Force Weather Agency, specifically to include future weather satellite data and products.

Since mid-2013, Doug has been the colead technical editor for the *Journal of Climate*.

"Becoming a technical editor and working for AMS allows me to keep in touch with the profession and to collaborate with authors to polish the journal articles for technical aspects and style," he comments. "I enjoy every aspect of working on the most popular AMS journal with the highest impact factor in its category (not including *BAMS*)."

Since joining AMS, Doug has become a volunteer observer for the Society as part of the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS), which "includes taking daily precipitation observations for this nonprofit, community-based network of volunteers of all ages and backgrounds who stress training and education using low-cost measurement tools with the web to provide the highest-quality data for natural resource, education, and research applications."

"I realize how important it is to get all citizens involved in monitoring our climate for awareness of climate changes," Doug continues, "and this is one way for me to do my part at work. At home I also maintain an automated weather station that uploads meteorological data to a public internet web service."

Doug has also become involved in the AMS computer technology working groups. Initial work with the technology group includes gathering information on the software and hardware used by AMS publications employees for performing their work and proposing standard computer solutions that can be implemented for all employee systems. Doug brought his prior skills from the research laboratory in this area, which included designing computer-data solutions for research projects and later managing similar solutions as part of the Weather Program Office.

"I joined AMS as a member in 1986, never thinking at the time that I'd one day work here," Doug concludes. "This is a terrific second career for me that I look forward to serving for a long time to come."

—Rachel S. Thomas-Medwid

OBITUARIES

RON PRZYBYLINSKI
1953–2015

The severe local storms community, including both research and operational meteorologists, lost one of its most distinguished members, Ron Przybylinski, on 12 March 2015. Ron passed away as a result of complications arising from treatments for cancer, which came as a terrible shock to everyone, as he appeared to be recovering from his illness and was about his normal business at conferences and work until his untimely passing.

Ron was born in South Bend, Indiana, in 1953, and obtained his B.S. (1977) and M.S. (1981) degrees in meteorology from St. Louis University. His full-time professional life began in 1981, when he joined the staff of the National Weather Service (NWS) office in Indianapolis, Indiana. In 1991, Ron was selected for the position of science and operations officer at the St. Louis office of the NWS, which he held right up to his passing. Although his service to those offices was at the highest levels, his influence and knowledge went well beyond them, spreading throughout the nation and the world through his publications and his many presentations.

Ron was a forecast meteorologist dedicated to the science of meteorology, applying scientific principles to his forecasts as well as contributing to that science by his research. His primary interests were bow echoes and quasilinear convective systems (QLCSs), especially when those systems produced tornadoes. Not only did he do the research, he served that science whenever the opportunity arose: he was a project leader for the Operational Test and Evaluation of the new WSR-88D Doppler radars in the 1980s. Ron also helped to organize (and participated in) the Bow Echo and Mesoscale Convective Vortex Experiment in 2003. As part of the COMET Cooperative Project with Saint Louis University, he investigated severe wind gusts from convective systems, starting in 1994. Ron also made time in his busy schedule to volunteer as a tornado damage investigator as a member of the NWS Quick Response Team.

In addition to his numerous scientific publications and conference presentations, Ron served a term on the Severe Local Storms Committee of AMS, as well as two terms as a councilor of the National Weather Association. In 1989, he was awarded the NWA Operational Achievement Award, and in 2003 he received the NWA's Fujita Award for his research achievements. The AMS awarded Ron the Charles L. Mitchell Award for outstanding service by a weather forecaster in 2012, and in 2013 he was recognized by NOAA with a Distinguished Career Award for his forecasting and research achievements.

Another important facet of Ron's career was sharing his passion for storms. It seemed he could always find time to talk at length with anyone who shared an interest in storms—with youngsters, students and NWS interns, and his professional colleagues. He helped to develop COMET training materials, particular those related to bow echoes and QLCSs, and shared his abundant experience and knowledge with many younger forecasters, helping them learn how to deal with diverse weather situations. Ron's infectious passion for storms was irresistible to those around him, inspiring everyone who knew him to work a bit harder and learn a bit more. He had an engaging manner that endeared him to all his friends

IN MEMORIAM
EUGENE RASMUSSON
1929–2015

and colleagues, and he also had a delightful sense of humor. Ron was a serious meteorologist, but he didn't take himself too seriously.

Ron Przybylinski can never be replaced, but those of us who had the distinct pleasure of knowing Ron and working with him are grateful for the legacy of professional dedication and knowledge that he left us. We miss him, and would like to convey our deepest condolences to his family and close friends.

—Charles Doswell

ABOUT OUR MEMBERS

Meteorologist **Michael Page** is joining the weather department at New England Cable News (NECN). Page goes to NECN from WFFF-TV FOX 44/WVNY-TV ABC 22 in Burlington, Vermont, where he has been the weekend meteorologist and environmental reporter since joining the stations in 2013.

Page also currently owns and oversees www.HinghamWeather.com, a local Boston-area weather website that he started in high school. Previously, he was an on-air meteorologist and environmental reporter while in college for WPSU-TV, The Pennsylvania State University's television station. He has also worked at WCVB-TV as a weather producer and intern.

Page is a graduate of Penn State, where he studied meteorology, weather forecasting, and communications. He recently received his Certified Broadcast Meteorologist Seal from AMS.

LIVING ON THE REAL WORLD

[Editor's Note: The following post is adapted from William Hooke's blog, Living on the Real World (www.livingontherealworld.org/). Hooke is the former director of the AMS Policy Program and currently a senior policy fellow.]

Women in Weather

Originally posted 26 March 2015

Yesterday, AMS and Northrop-Grumman put on a Google Hangout on Women in Weather.

Their tagline?

> *According to the National Science Foundation, out of the 14,000 professionals employed in atmospheric sciences, only 2,000 are women.*
> *That's only 14 percent.*
> *Join us on March 25 at 12:00 pm ET for a Google Hangout On Air as we discover all of the exciting possibilities women have in the weather enterprise.*

Compelling viewing! Built momentum as the hour went on, and could fruitfully have run a great deal longer. A lot to think about and digest.

Last evening, though, I heard from a colleague. Her message made me realize any contemplation on my part was way-too-shallow/complacent. She had this to say:

> I must confess that I really would prefer that some organization (maybe AMS) to eventually (no rush!) organize more discussions *among MEN* about the value that women bring to the profession. Explaining why/how/etc. the field would be less complete without them. It is clear that men hold many of the leadership positions in atmospheric science. They—not women—are the ones largely setting policies, mentoring/employing younger (often male) colleagues.
>
> I get a little frustrated when I see repeated, women-only lunches & discussions (tons of women in the room, with a small handful of men). They can be positive in that they are empowering (sisterhood!) and provide supportive words—analogous to how "Lean In" suggests that women need to be more assertive and step up to the table more. But it's my rather strong belief that I don't think anything will significantly change even if all women start doing this (which they won't) . . . it really needs to be MEN who take ownership on the issue and start convincing their male colleagues that certain strategies and steps are needed in order to increase the success rate of women in the field. . . .

When asked, my colleague was kind enough to let me repeat her remarks verbatim as a means of opening up the topic on LOTRW. You may agree or disagree with what she had to say, and perhaps after a night's reflection, she might want to tweak a word here or add a phrase there. Other viewers and members of our community would undoubtedly offer quite different takes.

Perhaps we can agree at the outset that there's never been a moment in history or prehistory when gender equality, with all its implications and ramifications, hasn't been a defining issue for the human race. Second, we've made little or no tangible progress across that vast span of years, despite the attention and writings of evolutionary and behavioral biologists, anthropologists, political and business leaders, and discussions of men and women, husbands and wives, in settings ranging from the United Nations, the halls of Congress and corporate boardrooms, to households, schools, churches, and coffee shops. Dysfunction is rampant, the topic consumes us, men continue to be complacent,[1] and women continue to be frustrated.[2] No papering it over; this is a serious problem. And (full disclosure—in fact, telling you only what you knew already), this single post, with its limitations of length and haste, cannot offer resolution.

The issue is profound; what's more, at its heart, the issue is an ethical, moral, and spiritual one. Given that, the issue has company. It's mirrored in failed race relations, our treatment of children, the elderly, the poor, and other vulnerable groups. So . . . with respect to these important issues—*not only are we failing to progress . . . but shame on us.*

That said . . . two comments. One is global; the other more limited, but holds global implications down the road.

First, although the issue is at its heart ethical, moral, and spiritual, it has transcendent and hugely practical implications. **Our failure to ensure that women are at the table as decisions are made locally everywhere and worldwide in every context compromises our ability to solve the intractable twenty-first-century real-world problems we face**. This is not a new thought. Bernard Lewis, a noted Middle East scholar, addressed this in a little book he wrote in 2002 titled What Went Wrong: The Clash between Islam and Modernity in the Middle East. Lewis's idea is that for the past 500 years, the once-dominant Islamic world has failed to modernize or to keep pace with the West. He notes that many Islamic scholars and leaders see this as opening the door to disastrous Western influence across the region. He and others speculate that this failure to modernize has come about because women have been excluded from decision-making and influence.

Closer to home, we can revisit and expand a bit on some of the thinking in *LOTRW the blog* and *LOTRW the book* (pp. 115–119). There it's suggested we face an obdurate three-fold simultaneous challenge: garnering natural resources, especially, water, food, and energy; protecting the environment; and building resilience to natural hazards. Our only option? To bring to bear the whole of the world's brainpower, in its fullest diversity.

Here's some homely speculation to illustrate the idea. It's not good science; it's not even science. But please indulge me. It goes like this.

Suppose we have some number, say 12 people, in a room trying to solve a tough problem. Let's suppose that all of them are male. Let's also suppose, life being what it is, that most of the diversity in the room is embodied largely in the first six men; those last six men more-or-less duplicate the range of thinking already represented at the table. They don't add that much. Now let's suppose further that the spread of problem-solving possibilities the discussion brings to light changes with the size of the group in a combinatorial or factorial way rather than in a purely linear way. In other words, the sixth person coming into the room doesn't just add 17% to the problem-solving capabilities of the room. Instead, because he can engage any of the other individuals in subconversations or groups of two or more in subconversations that'll lead along additional paths to novel ideas, that he's enhanced the problem-solving power of the room considerably, maybe not [by] a factor of six, but by a significant amount. Note, however, that the last six men coming into the room don't add much to the problem–solving power at all. They duplicate what's already there.

Now . . . replace that second contingent of six men with six women, so we have six men and six women. Those six women aren't duplicating the six men; they're bringing different experience and perspective. Those additional six people haven't just doubled the problem-solving power of the people in the room. Again, because the new participants will partner up with multiple subsets of people in the room in differing ways, and because they're bringing fresh perspective to bear, and because the discussion is enriching in a combinatorial way, they're increasing the range of available options by factors of ten or hundreds.

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[1] Word software offers a host of horrible synonyms for this word: *satisfied, self-satisfied, smug, unworried, content, contented, self-righteous.*

[2] The Word software synonyms here are chilling: *unfulfilled, irritated, unsatisfied, upset, angry, exasperated, discouraged.*

Easy to find fault with the details here. But not the flavor. By bringing to bear the full diversity of society (starting with gender, for today's purposes) to solving our problems, we're not just doubling our chancing of working through to effective solutions and coping strategies, we're increasing our social brainpower manifold times.[3]

Second, just a bit closer to home, here at the American Meteorological Society we've been running a leadership development program for early-career scientists—the Summer Policy Colloquium—for the past 14 years. We've put 500 people through the program over that span of time.

[3] There's a huge literature on the subject of diversity and problem solving; Googling that phrase provides a starting point for diving in. It would be useful if some of the social scientists among the readership could offer links or references to specific peer-reviewed literature or research on this subject they've found credible.

Half the participants have been women. This is not an artificial result produced by a quota system of some kind; applicants for the Colloquium self-select. Women have been drawn to the challenge and supported by their host institutions out of proportion to that 14% statistic for the demographics of our field mentioned in the Google Hangout.

Ask yourself: what does that say about the future for our field—and by implication, for the fortunes of seven billion people wrestling with resource, environmental, and hazards issues? A heartening sign? Or just more complacency on my part (male, and a fairly senior one at that)? After yesterday's Google Hangout and correspondence, I'm hesitant to say.

I'll know better when/if I hear back from my colleague, or from you. She/you are better positioned to judge.

(Editor's note: William Hooke can be contacted at hooke@ametsoc.org.*)*

AMS STATEMENT

WEATHER ANALYSIS AND FORECASTING

An Information Statement of the American Meteorological Society

(Adopted by the AMS Council on 25 March 2015)

This Information Statement describes the current state of the science of weather analysis and forecasting from short-term severe weather events to monthly and seasonal forecasts.

INTRODUCTION. The nation's Weather and Climate Enterprise is typically grouped into three sectors: government agencies, academic institutions, and the private sector. These three sectors play vital roles in providing products and services to the user community, which includes the general public as well as weather-sensitive government agencies (e.g., the military, Homeland Security, Environmental Protection Agency, numerous state and local offices, etc.) and private industries (e.g., energy, agriculture, transportation, etc.).

Forecasters are tasked with synthesizing available observations from multiple platforms (including surface observations, weather balloons, radar, and satellite), numerical guidance from computer model forecasts, scientific theory, and experience-based intuition to arrive at a forecast. The forecast process is often collaborative, with teams of meteorologists routinely integrating new information into the forecast as the event approaches. Increasingly, forecasters are also responsible for effectively communicating the forecast and its anticipated impacts upon life and property to various stakeholders, including the public.

The impacts of meteorological phenomena upon both life and property, whether short-lived or long-lasting in nature, are substantial:

- Nearly 90% of the emergencies declared by the Federal Emergency Management Agency are weather-related.
- More than 7,000 road fatalities per year can be directly or indirectly attributed to weather.
- Approximately 70% of air traffic delays are caused by weather, at a cost of about $6 billion per year.

- Heat waves kill an average of about 175 people each year in the United States.
- U.S. utilities save more than $150 million per year using 24-hour temperature forecasts to meet electricity demands most efficiently.
- Reducing the length of coastline under hurricane warnings involving the need for evacuations saves up to $1 million per coastal mile in evacuation and other preparedness costs.

HOW ARE FORECASTS MADE? *Analyses of weather data.* Forecasting the weather begins by continuously observing the state of the atmosphere, the ocean, and land surface. The World Meteorological Organization provides the framework for an evolving worldwide suite of observing systems, such as satellites, radars, and surface weather observations that aid in monitoring these conditions. Observations from private citizens, particularly of precipitation type and severe weather, are increasingly available through social media, platforms such as the mobile Precipitation Identification Near the Ground (mPING) initiative, and through organized efforts such as the National Weather Service's Cooperative Observer program and the Community Collaborative Rain, Hail and Snow (CoCoRaHS) network. Although major research challenges remain, scientists have made considerable progress in developing mathematical techniques to integrate these observations into snapshots of the land surface and atmospheric state at any given time. These analyses serve as the foundation for weather prediction on scales from individual clouds to regional severe-weather events and global patterns. Analyses of current and past weather support many diverse environmental applications, including fundamental scientific investigations of the climate system.

Forecast techniques. For time scales on the order of a few minutes to a few hours, forecasters rely heavily on an extrapolation of current weather trends. Such forecasts are often called "nowcasts." For instance, radar animations may be examined to predict the timing of a squall line while also taking into account changes in the environmental conditions with which the storm may interact. Nowcasting techniques often rely upon extrapolation, statistics, and experience-based intuition rather than sophisticated atmospheric models, yet they can be highly accurate on short time scales.

At time scales of a few hours to a month or more, numerical weather prediction (NWP) is the dominant forecasting technique. NWP, or computer-based modeling of the atmosphere, involves representing the current atmospheric state on a three-dimensional grid, applying the physical and dynamical equations that govern how the atmosphere will change in time at each grid point, and repeating this process to generate a forecast of desired length. Computer memory and processing limitations dictate the number of grid points and complexity of small-scale physical process parameterizations that can be reasonably used, with more points generally leading to a better solution. Modern NWP models are developed and maintained in collaboration among multiple agencies and are often coupled with models of the land surface and ocean.

Despite their sophistication, models suffer from shortcomings, such as an incompletely observed atmosphere, insufficient computing resources, and imperfect simulation of small-scale phenomena, such as clouds and precipitation. Systematic forecast evaluation and verification is conducted to quantify model behavior and to identify specific model capabilities and shortcomings. Meteorologists use two approaches to address these shortcomings:

- Application of statistical techniques to correct systemic biases. Past model forecasts are compared to observations over a long period of time to quantify expected errors. The result of this analysis is used to improve output from future model forecasts of similar situations.
- Using an ensemble of models to explore forecast uncertainty that results from the chaotic nature of the atmosphere and errors in the modeling system. Even with a perfect model, very similar initial states of the atmosphere will sometimes become very different in time. To capture this possible variability in the solutions, an ensemble is composed of many slightly different forecasts, with the differences in how each forecast is obtained meant to mimic modeling and observing system error. If each individual forecast is equally likely and, if enough sufficiently variable forecasts are obtained, the probability of different forecast outcomes can be quantified.

Role of forecasters. Even as models and objective guidance tools have improved in recent years, highly skilled forecasters remain an integral part of the current state of forecasting. Forecasters are continually trained on how best to use the latest data, model outputs, and forecast tools. Forecasters continue to add value to NWP guidance for daily forecasts, watches, and warnings, especially for high-impact events, and specifically in the 12–48 hours of the forecast period. From 1992 to 2012, National Weather Service forecasters achieved a 20%–40% improvement over two commonly used numerical models for a 24-hour forecast of one inch of precipitation over one day, even as the NWP guidance continually improved.

Communication of weather forecasts. Methods for the delivery of weather information continue to evolve with advances in technology and social science research, which includes the disciplines of communication, psychology, geography, economics, and anthropology. Private citizens, businesses, and institutions have become far more sophisticated in their receipt and use of weather information due in part to the constant expansion of public and commercial weather products through technologies such as the Internet, wireless communication devices, electronic message signs, and other media. For example, location-specific information including hourly forecasts, storm-based severe weather warnings, and radar data is delivered directly to smartphones.

Most forecast products and services are based on discrete values or thresholds. These services provide users with the best estimate of what will happen. However, for optimal decision-making, users need to consider the range of possible events beyond the most likely outcome in determining the appropriate action. They also need information about the likelihood and probable strength of potential high-impact events as early as is practical, given that the increase in uncertainty with time is a complicating factor. This expression of forecast uncertainty is an area warranting improvement and will require increased communication between users and producers of weather forecasts, as well as research on how best to represent this uncertainty (e.g., graphically, with percentages, through text explanations, etc.).

HOW RELIABLE ARE TODAY'S FORECASTS? *Skill, predictability, and lead time.* The skill of a forecast refers to how accurate the forecast is compared to some reference or baseline prediction, such as a forecast compared against climatology or persistence of current conditions. The predictability of meteorological events differs based on the size and timing of the event. Larger systems are inherently more predictable at a given lead time than are smaller ones. Predictability also decreases as the lead time—the amount of time between the present and when the phenomenon is expected to occur—increases.

Predictability is further limited by an incomplete representation or, at times, full understanding of the relevant physical processes, inadequate observations and methods for their incorporation into numerical model forecasts, and limitations in computational power. Nevertheless, as the examples below illustrate, advancements in all of these aspects in recent years have resulted in more skillful forecasts across diverse meteorological phenomena and forecast lead times.

Short-range forecasts. For lead times of approximately twelve hours to two days, short-range forecasts are typically issued for meteorological phenomena, such as tropical storms, hurricanes, and frontal systems and their accompanying sensible weather elements (e.g., temperature, wind, and precipitation). Many of these forecasts are significantly improving: 2-day National Hurricane Center hurricane track forecasts issued in 2012 had an average error of 79 miles as compared to 140 miles in 2002 and 192 miles in 1992. Likewise, 2-day NOAA Weather Prediction Center forecasts of 24-hour accumulated precipitation issued in 2012 were as accurate as 1-day forecasts in 2006.

Medium-range forecasts. Defined as forecasts with lead times of two to seven days, medium-range forecasts are most successful for meteorological phenomena that stretch across areas of a thousand miles or more, or for larger-scale conditions that set the stage for development of smaller phenomena, such as severe thunderstorms. Over the past three decades, the skillful range of medium-range forecasts has been extended by roughly one day per decade. Specifically, five- and six-day surface temperature forecasts issued by the National Weather Service had the same level of accuracy in 2012 as did three- and four- day surface temperature forecasts, respectively, in 1992.

Extended-range forecasts. Extended-range forecasts are typically issued for meteorological phenomena that cover areas ranging from thousands of miles to the size of a continent, and involve lead times of one to two weeks. Presently, forecasts of daily or specific weather conditions do not exhibit useful skill beyond eight days, meaning that their accuracy is low. However, probabilistic forecasts issued to highlight significant trends (e.g., warmer than normal, wetter than normal) can be skillful when compared to a baseline forecast. For example, the NOAA Climate Prediction Center operational 8–14 day temperature forecast skill in 2013 was approximately equal to that of operational 6–10 day temperature forecasts from the late 1990s, again demonstrating an increase in forecast success over time.

Monthly and longer-range forecasts. Finally, monthly and seasonal forecasts are typically issued for meteorological phenomena that cover areas ranging from the size of a continent to the planet as a whole. Skill in monthly and seasonal forecasts is extremely variable from period to period, but the skill of NOAA Climate Prediction Center one- and three-month forecasts of temperature and precipitation increased by more than 25% between 2006 and 2013. Increases in forecast skill at these lead times can largely be attributed to improved understanding of and ability to forecast major modes of large-scale climate variability such as the El Niño-Southern Oscillation and Madden-Julian Oscillation.

USERS OF WEATHER INFORMATION AND FORECASTS. Government agencies, businesses, academia, and the general public have developed innovative ways to use forecast products to increase economic efficiency and productivity, advance scientific research, and reduce exposure to weather risks. Across the entire spectrum of users, there are growing requirements for accurate forecasts with greater temporal and spatial specificity. The demand for accurate, specialized forecasts from various economic sectors has led to the continued growth of the U.S. weather industry, particularly private forecast services.

During the past 10 to 15 years, improvements in forecast quality have enabled the development of advanced and customized applications to suit the needs of various user groups. The need for different levels of detail is dictated by how the information is to be applied. For example, during a winter storm, different users need specific information relevant to their business operations. The general public is typically most interested in weather conditions that may impact their activities and safety. Specialized users, such as utility companies, public health/air quality sectors, road crews, and airlines need much more specific forecasts (e.g., where will the snow fall, how much, and when) to help determine the need for changes in their operations. These users require a level of specificity not available from general-purpose forecasts. Adjustments in forecasts for those specifics require concentrated, continuous monitoring of many parameters by highly skilled forecasters as well as involving those users in collaborative design of future forecast products.

OPPORTUNITIES FOR FUTURE IMPROVEMENT. Opportunities exist for increasing forecast skill at all time ranges. However, realizing these opportunities will require further research; close international cooperation and coordination; improved observations of the atmosphere, ocean, and land surface; and the incorporation of these observations into numerical models. Also, benefit will be derived from higher spatial resolution of numerical models; increasingly powerful supercomputers; wider use and improvement of model ensembles; the development of data mining and visualization methods that enable forecasters to make better use of model guidance; and collaborative forecast development activities among operational forecasters and researchers.

Beyond improving the forecast itself, improvement in the communication and best use of forecast information is also needed. Research integrating social science is key in identifying opportunities for future advances. For example, research conducted by social scientists across multiple disciplines has found that delivering weather warnings across multiple media increases the likelihood that people will get and act upon this information. Scholars have conducted numerous studies on different public groups about perceptions of risk and uncertainty. They are also working to explore the relative value of effective communication of accurate weather forecasts to appropriate decision makers. Collaborative research with social scientists will also enable forecasters to codify best practices in forecasting philosophy, communication, and training amid rapid technological change. An increase in the presence and use of social media is contributing to additional avenues for providing weather information and collecting real-time observations.

CONCLUSION. In summary, weather forecasts are increasingly accurate and useful, and their benefits extend widely across the economy. While much has been accomplished in improving weather forecasts, there remains much room for improvement. The forecasting community is working closely with multiple stakeholders to ensure that forecasts and warnings meet their specific needs. Simultaneously, they are developing new technologies and observational networks that can enhance forecaster skill and the value of their services to their users.

[This statement is considered in force until March 2020 unless superseded by a new statement issued by the AMS Council before this date.]