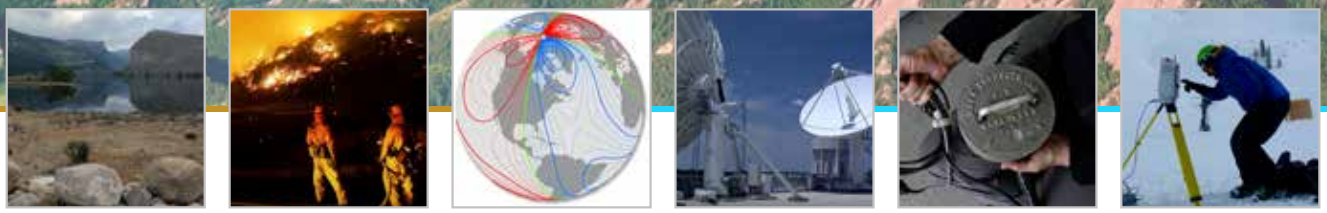
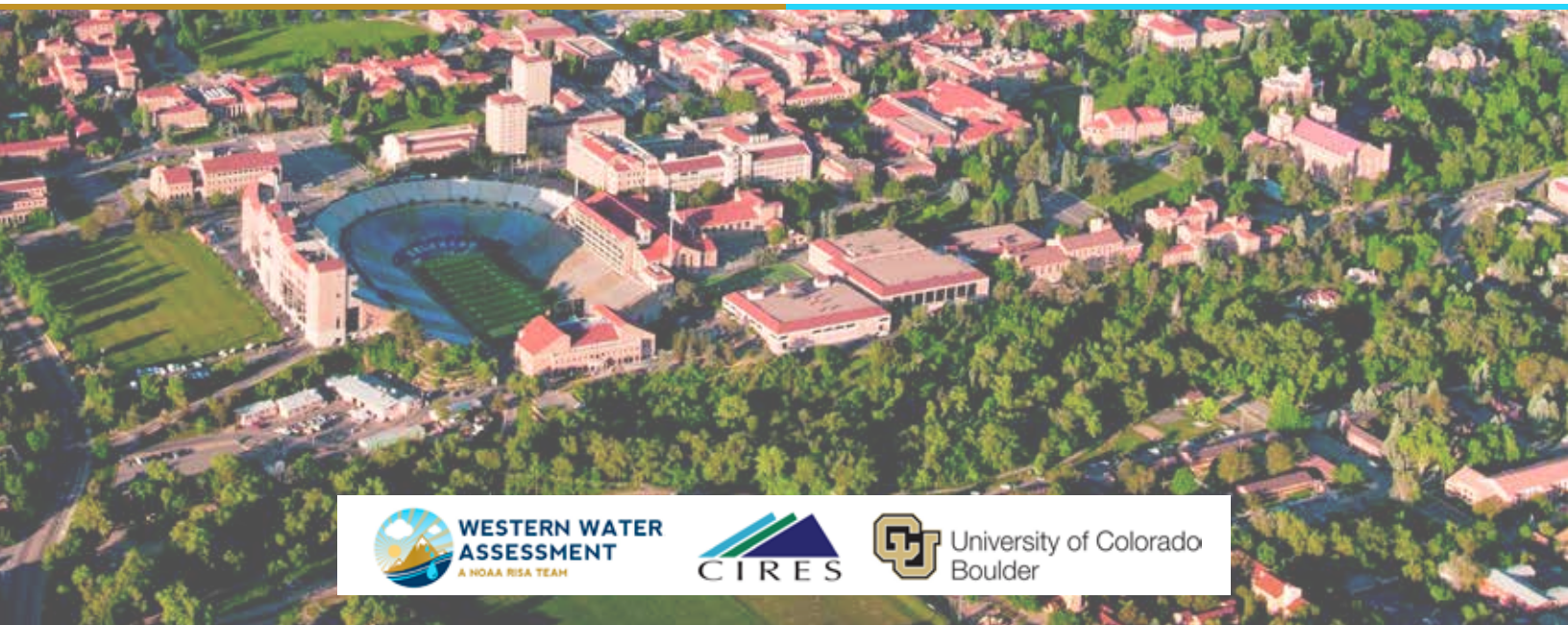


Making Research More Usable at CU Boulder

Western Water Assessment
Cooperative Institute for Research in Environmental Sciences
University of Colorado Boulder



MAKING RESEARCH MORE USABLE AT CU BOULDER

February 2018

Western Water Assessment

Cooperative Institute for Research in Environmental Sciences

University of Colorado Boulder

This guide was written by Lisa Dilling, Katie Clifford, Elizabeth McNie, Jeff Lukas and Ursula Rick of Western Water Assessment. We thank the individuals mentioned in this guide for their willingness to contribute examples of how to make research usable. Funding for the guide was provided by the Research Innovation Office of the University of Colorado Boulder. Western Water Assessment is a Regional Integrated Sciences and Assessment (RISA) program of the National Oceanic and Atmospheric Administration. All views expressed herein are the responsibility of the authors.

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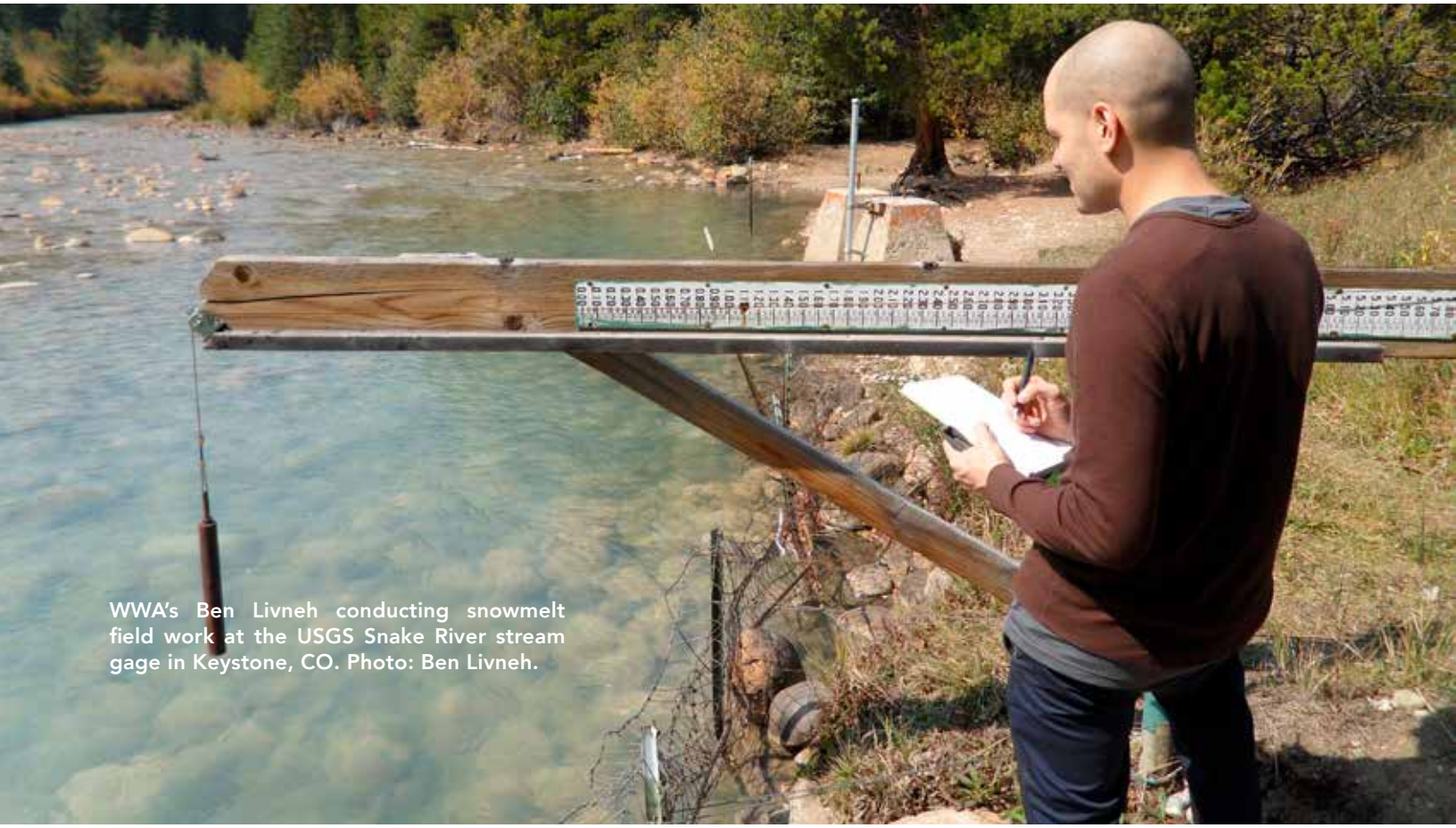

WWA's Ben Livneh conducting snowmelt field work at the USGS Snake River stream gage in Keystone, CO. Photo: Ben Livneh.

MAKING RESEARCH MORE USABLE AT CU BOULDER

Despite its potential, research is often critiqued for being not as usable for decision making in practice. This guide provides tangible, tested ways for making science more usable based on our experience in the Western Water Assessment as well as other input. It also highlights examples of researchers at CU Boulder who have produced usable research to serve practical needs. We recommend several possible options for overcoming barriers to making research at CU Boulder more usable.

We need to make research more usable

As a society, we rely on science and technology more than ever.

Making scientific research "usable" means ensuring that the results of research are available and relevant for decision makers in areas such as health care, resource management, land-use planning, business management, disaster prevention, transportation, and agriculture. Making research usable encompasses a wide variety of situations, from the casual consulting of information for general interest, to the input of data into formal decision support systems or models. We recognize all of these forms of use as being valuable and worth supporting in making research more usable.

For the purposes of this handbook, a decision maker is someone outside of the university research community who makes decisions in which scientific information and knowledge have some bearing. Decisions are specific to a person's role and responsibility within an organization—and the information needed can thus be very specific as well (see "What is a Decision Maker" on page 5).

But wait, isn't research usable already?

Some research results are indeed used by decision

makers, but many others have the *potential* to be used by decision makers—and are not.

Not all research is intended for direct use by decision makers, nor does science need to be used outside of academia. But there are many research programs and many researchers who are pursuing particular lines of inquiry primarily ***because*** they ***want*** their results to be useful to society. Studies of the use of science over the past 20 years, however, have shown that for a variety of reasons, decision makers often don't end up using the results of research that may be relevant to their domain.

One barrier is the communication and dissemination of research. For example, if research results are conveyed only through peer-reviewed journal articles, that information is unlikely to reach the vast majority of decision makers. Other pathways such as direct conversations between managers and researchers are likely to be more fruitful.

However, it's ***not just a matter of better communicating research*** results through other media, although those efforts are certainly welcome and important.

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WHAT IS A DECISION MAKER?

A decision maker is anyone who contributes to making a decision within an organization, including, for example, a technical analyst, a forecaster, a program manager, or a program director. Each type of job may have a different need for information and a different set of concerns, even within the same organization.

For example, consider a municipal water utility. Different divisions within a utility are responsible for guaranteeing that: a supply of water is available; water supplied to customers is of adequate quality; the utility can generate sufficient revenue and stay solvent; the utility is encouraging sufficient conservation and demand management; waste water is being treated adequately; there is sufficient water pressure for fire-fighting; the utility is prepared to meet water needs in the future, that environmental requirements are being met; and so on. While employees of a water utility are all engaged in the business of providing clean drinking water, each one has a particular outlook on what information is most relevant.

No single research project can address all of the needs for scientific decision-support in a utility, but this also means that there are many potential entry points for research to make a difference. It's essential that researchers understand where their project may be relevant and engage with the right contacts from the organization they hope to work with.

The Binney Water Purification Facility in Aurora, Colorado. Photo: City of Aurora, Colorado.

CHARACTERIZING WATER STRESS ON THE WIND RIVER INDIAN RESERVATION

The beautiful snowy peaks of the Wind River Range are one of the main sources of water for the tribes that make their home in the Wind River Indian Reservation (WRIR) in west-central Wyoming. Climate scientist **IMTIAZ RANGWALA** and his team, with CIRES and the NOAA Physical Sciences Division, has been working with the Eastern Shoshone and Northern Arapaho tribes' water engineers to better understand the climate and hydrological characteristics in the region, and their changing trends, to better prepare for extremes related to too little or too much water. The mountain snowpack that drives the tribes' water supply became a "motivating theme" for Imtiaz in his quest to understand whether the range was seeing changes in the snow-to-rain ratio, which has consequences for flooding and drought management on the reservation.

Working with a collaborative team that consisted of social scientists, ecologists and physical scientists from different institutions from across the region, Imtiaz built trust with the tribal water engineers through shared colleagues and in-person meetings. The team came to him to understand the underlying physical reasons for a drought crisis in late summer 2015 when they were unexpectedly left with inadequate water supplies for irrigation for the last two weeks of the growing season.

Imtiaz and his team worked together to bring in data sources beyond the in-situ SNOTEL (snowpack monitoring) sites, including gridded and satellite data and snow modeling. For diagnosing the water

Tribal Water Engineers with scientists from different institutions involved on the project visiting the Anchor Reservoir in the Wind River Indian Reservation, Wyoming. Photo: Candida Dewes.

stress during the 2015 growing season, they also evaluated the utility of a new drought index, the Evaporative Demand Drought Index (EDDI), which showed the evolution of the drought at weekly timescales that corresponded with the tribal water engineers' experience. Their team was able to report back the findings that the 2015 flash drought had been set up by a pattern earlier in the year of a warmer winter, when less precipitation fell as snow and earlier runoff coupled with insufficient storage created the water shortage. This work has led to better understanding of the tribes' climate information needs and forged strong network for future interactions.

Imtiaz's lessons for making research usable:

- Sometimes it's hard to identify the key decision maker who will use your work in an organization. Persistence and time can help identify the right person.
- There is a lot of back and forth needed when sharing information and understanding the question of interest for stakeholders. Sometimes the organization or culture involved can make that back-and-forth process more or less difficult.
- Projects do not always proceed linearly. Sometimes the stakeholder has to digest new information and think about the next steps. Researchers need patience and a willingness to wait for the time to be right for engagement.

Build on the south fork of the Little Wind River, the Washakie Reservoir (in the picture) is critical to water management in the southwestern part of the Wind River Indian Reservation, Wyoming. Photo: Imtiaz Rangwala.

Outflow from the Bull Lake Reservoir in the Wind River Indian Reservation, Wyoming, that meets the main artery of the Wind River a short distance away. Photo taken by Imtiaz Rangwala on a tour of the major water bodies on the reservation organized by the Tribal Water Engineers.

In many cases, ***the results of research aren't usable at all, or aren't as usable as they could be, because the research process itself is not informed by the problems that decision makers face and the contexts in which they make decisions about those problems***. This lack of connection means that researchers often are not aware of the types of information that could be most useful to decisions, the timing of when information is needed, the format or language that is most accessible, or the dissemination pathways that are most trusted.

These challenges call for a ***more deliberate connection between science and the needs of decision makers***, through ongoing interactions between decision makers and scientists themselves or through others tasked with interpreting and convening spaces for dialogue, interpretation, and innovation.

Usable research encompasses many dimensions, but at its foundation, it is attentive to the decisions and needs of those outside of academia, rather than being solely focused on the more recognized goals of science such as advancing theory and making discoveries for their own sake. That said, producing science that is usable does not mean it can't be creative and novel. Many fundamental discoveries have been made while in the pursuit of solving a practical problem.

So how can we make our research more usable?

Researchers have followed many different pathways to make their work more usable to decision makers. The path a project takes depends greatly on who is involved and on *when* the researcher decides to try to produce research that is outside of the academy (pre-project, during the project, post-project). It also depends on what resources are available—especially personnel and time, which are always in short supply. What is common to all pathways is that at some point, the needs of decision makers are considered and the research products are shaped by those considerations, or the research process itself is shaped by them.

In some cases, the information produced by research is close to being usable but needs further work to be relevant and timely (e.g. adjusted for the appropriate scale, units, and timing of delivery). In other cases, it is already being used in a limited way but perhaps not as well as it could be (e.g. there is a lack of understanding about what the data mean or how they are relevant to the problem at hand) or it is being used incorrectly or is simply not trusted by decision makers. In still other cases, knowledge that could be usable does not yet exist—and knowledge needs to be generated in collaboration with those who would use it, a process called 'co-production.'

Below we outline three general pathways for making research more usable, with differing degrees of engagement with decision makers. Note that there are many other potential pathways, as indicated by the case studies.

We should emphasize there are also options for *who* is involved in all of these pathways—it may be that

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WHAT IS A BOUNDARY ORGANIZATION OR INFORMATION BROKER?

Boundary organizations or information brokers act as a two-way conduit between decision-maker communities and the research community. They mediate the transfer and creation of knowledge and buffer each side of the boundary from potential negative consequences such as politicization of science. An information broker is simply an individual working in this type of role. Importantly, boundary organizations or brokers "own" the process of creating usable science, and are responsible to both sides of the "boundary" to ensure that they do the best job possible in connecting research to users to create usable science.

When working with a boundary organization, it is critical to understand what the boundary organization itself does, and to be comfortable with the role it plays. A key question is whether the boundary organization functions as an advocacy organization or not. If so: What does it advocate for and are you comfortable with that stance?

Some examples of boundary organizations that focus on knowledge brokering are:

The Cooperative Extension System, comprised of programs at universities and counties across the United States that connect agricultural producers and consumers with information (https://nifa.usda.gov/extension).

Photo to the right: USDA National Institute of Food and Agriculture.

The NOAA Regional Integrated Sciences and Assessments (RISAs), university-based programs that connect climate science and information with local and regional decision makers. The authors of this guide are associated with the RISA at the University of Colorado Boulder/CIRES called the Western Water Assessment (http://wwa.colorado.edu).

Image to the right: Currently funded RISAs. Image: NOAA Climate Program Office.

Community Engagement and Design Program (CEDaR), a collaboration that connects research and teaching at CU Boulder with cities and other local partners to develop sustainable solutions to problems in the built environment (https://www.colorado.edu/cedar).

Photo to the right: Community Engagement Design and Research Center, University of Colorado Boulder.

CONNECTING THE DOTS FOR BETTER EMERGENCY MANAGEMENT

Whether mining emergency response situation records, tweets or other posts from social media, **LISE ST. DENIS** at CU's Earth Lab sees a world of opportunity to improve our response and planning for disasters. Coming from a background of working with emergency responders, Lise now conducts research using computer science to put together data sets across widely different sources to better support emergency management in the field. Her current project focuses on mining the daily "Situation Reports" from the incident commands which are set up during large-scale emergencies (i.e. those requiring the establishment of an Incident Management Team). While these reports cover a wide range of emergencies, over 95% of the actual reports nationally are fire-related. The data included in Situation Reports provide a wealth of information on decisions about how resources were allocated, how the physical hazard was playing out on the ground, and whether the measures taken were effective or not. By presenting the data from these incident reports in a comprehensive, user-accessible database, Lise hopes to make these usable for both practitioners and researchers. For example, researchers can connect these socially-relevant data to remotely-sensed data on landscape condition, weather patterns, and vegetation, to understand how physical and biological factors intersect with fire management decision making. "It makes a whole different set of questions possible," says Lise.

Fire management practitioners have already shown great interest in Lise's dataset and the flexible application programming interface (API) she is building to let other technical teams access the data easily. Because of her previous experience with responders, she held a small workshop with a group of practitioners to provide early feedback and input on the shape the product should take. She is still in the process of developing the final product, but is already fielding multiple expressions of interest in her work each week not only from fire managers and researchers but companies and organizations

Photo: Washington State's Wildfires, 2015. Credit: NBC News.

interested in studying the relationship between social and physical properties of hazard management. Her ultimate goal is to build a flexible, web-based interface that any fire manager, emergency response practitioner, or even a non-expert member of the interested public could use to look at hazard patterns and trends in their area.

Lise's lessons for making research more usable:

- The only way to learn how to make research more usable is to "jump in and do it"—or "learn as we do".
- Building trust is important. Lise establishes trust in the data by a "commitment to open and reproducible work." Every dataset, script used to work with data, analysis, etc. are published as open source, meaning retrace the steps that led to the final data set.
- It's important to start the conversation going early with practitioners and engage with them about data, perhaps even before you have specific use cases in mind. Hearing from practitioners not only keeps the research relevant but also can help illuminate nuances of the data and correct your own faulty assumptions.
- It's a good idea to start small with a practitioner community, working with those you know and who trust you and expand the scope from there.

More than 10 wildfires burned over 200,000 acres in Southern California in October 2003, many of them started by humans. This satellite image shows strong winds carrying smoke over the Pacific. Photo: MODIS Rapid Response Team/NASA.

The 23rd annual session of the Conference of Parties (COP 23). Photo: Timothy Molnar.

the researchers themselves are directly involved in the process of making science more usable, or, that the researchers connect with decision makers via others who are *information brokers* or *boundary spanners*, whether part of a *boundary organization* or operating individually (see "What is a Boundary Organization or Information Broker" on page 9).

EXAMPLE PATHWAYS TO USABLE SCIENCE

Pathway 1 (least intensive involvement of decision makers): Improved dissemination and translation of existing research findings or data (post project)

In some cases, investigators discover—only after the conclusion of a project—that the findings could be used by decision makers. Even though the research is completed, it is still useful to determine what findings are relevant and how to make them accessible and usable to the intended audience. This follow up process may involve substantial additional work.

Pathway 2 (moderate involvement): Engagement with decision makers during the course of a project that was originally scoped without their input

In some cases, as researchers proceed with a research project, they realize that their work could be used by people outside of academia, or maybe they had that hope from the beginning but the project was originally scoped without decision makers. In this case, researchers could engage decision makers mid-way, to adjust the scope of their research or outputs to be more usable.

Pathway 3 (most involvement of decision makers): Co-production: Engagement with decision makers throughout scoping, research design, conducting research, and sharing results, etc.

Sometimes the research that is needed for decision making simply doesn't exist, and has to be generated, ideally through a process of co-production. Co-production brings researchers and decision makers together as partners from the start to conduct the research; from defining the questions, iterating on the project trajectory as it proceeds, and evaluating and assessing project outcomes. The research question itself is co-designed from the beginning (with the researchers and the decision makers), including scoping the work, writing the proposal, and conducting the research. Co-production is deliberate and as such processes must be put in place to ensure close connection of research and decision makers throughout the research project.

STEPS FOR MAKING YOUR RESEARCH MORE USABLE

There is no one "right" way to conduct processes or gather information to make research more usable. Below we describe 10 ways to promote the types of interactions between researchers and decision makers that can make your research more usable. These steps can be applied to any of the pathways identified above.

1. Identify the types of decision makers who might benefit from your work

It's important to understand which organizations make decisions that rely on your information (if you don't already know them). Even if you know the practical setting fairly well, learn about the decisions themselves and what different decision makers within organizations are most concerned about; this is critical to the efficient production of usable science. Some specific ideas to help you learn more about organizations' concerns:

- Read trade magazines and websites.
- Attend meetings of professional or trade organizations—these are generally a completely different crowd than your usual academic conference and you can expect a focus on practical information and real-world applications.

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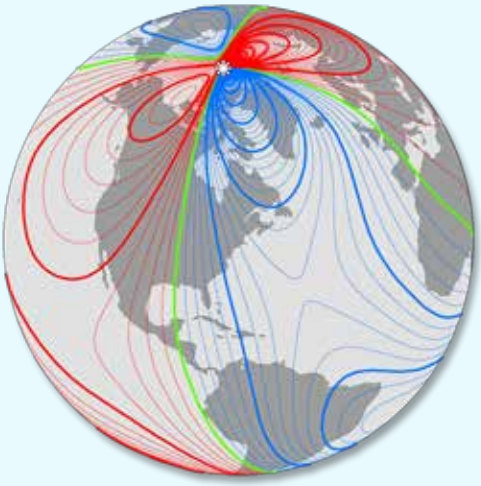
KEEPING TRACK OF MAGNETIC NORTH

ARNAUD CHULLIAT was lured from doing research on the earth's core in Paris, France, to Boulder, Colorado, to lead the geomagnetism team at CU Boulder/NOAA. The World Magnetic Model (WMM) represents the earth's changing magnetic field and is critical for navigation and device-orientation applications. Although it has been around since the 1970s, the need for more sophisticated models has grown: Today, the WMM has over 8,000 institutional users and is relied on by NATO, the U.S. Department of Defense, and the UK Ministry of Defence. Much closer to home, the WMM is almost certainly pre-installed on your personal iOS or Android smartphone.



Magnetic declination (angle between local magnetic field and direction of geographic north) in 2015 from the World Magnetic Model. Contour interval: 2 degrees, red contours positive (east), blue negative (west), green zero line. White star shows location of magnetic dip pole. The fastest declination changes are observed near the (drifting) magnetic pole. Credit: NOAA/NCEI.

Arnaud and his team are constantly listening to feedback and reaching out to existing institutional users of the WMM to understand their needs for new applications. For example, the need for higher accuracy from the Department of Defense, and need for higher definition from drilling companies have resulted in the Enhanced Magnetic Model (EMM) and the High Definition Geomagnetic Model (HDGM), respectively. When users download any of the WMM family of products, they fill in a short survey to let the team know what the model is being used for, by what institution, and sometimes a few specialized questions about the use context. This survey is brief, per NOAA rules.

Arnaud and his group also conduct fundamental new research on geomagnetism, often motivated by questions that come in from users. His group publishes academic papers and writes proposals, and his work really exemplifies the notions of "use-inspired basic research"—demonstrating that academic pursuits and application to society needs are not necessarily antithetical. Users trust in the WMM because of its long history, partner support, and responsiveness to needs, and the project has been consistently funded as a result.

Arnaud's lessons learned in creating usable science:

- Doing fundamental research that is useful to society is highly rewarding.
- Producing usable research is a two-way process that doesn't happen overnight.
- To ensure that research directions reflect the needs of users, he and his team engage in a lot of back-and-forth conversation with users. It's important to learn about what the other side of the equation is doing. Users can learn about what is feasible from the science side, and scientists learn about what the decisions and use context are from the government and industry side.
- One-on-one interaction is important. Arnaud and his team meet up with users at industry conferences and government and industry representatives visit his lab.
- The time scales of industry are often much more rapid than a typical academic project cycle. An industry user might want to know what can be done in six-months to a year rather than in three-to-five years.

For more information: https://www.ngdc.noaa.gov/geomag/WMM/uses.shtml

- Introduce yourself and your team to a local organization, even if you aren't sure yet exactly how your research might connect. You can gain valuable information on the field from your local contacts and build bridges to the community.

- Embed yourself temporarily in an organization to see it from "the inside." This kind of intensive commitment takes special circumstances and professional flexibility.

2. Meet with decision makers

Once you have some sense of the landscape of people who might be interested in your research, it's helpful to have direct meetings with them. This can start with a less-formal conversation or meeting involving a handful of people from one organization and your research team. It may progress to larger and more formal interactions like dedicated workshops (see below). While much information can be gained from websites, newsletters, and the like, nothing substitutes for face-to-face meetings and direct relationship-building. Creating and fostering "social capital" or effective partnerships and network connections, is essential to making research more usable.

3. Take advantage of focusing events

A focusing event is a newsworthy event or crisis that draws attention to an issue for a period of time from policy makers, the public, and others outside of the technical expert community. A disastrous flood or hurricane, an economic crisis, a fuel oil shortage, or an earthquake may raise questions about prevention and preparation for future events. At these times, decision makers seek more information. Focusing events can present an opportunity for you to connect with them and learn about their critical questions.

4. "Seed" the dialogue

While you might want to keep an open mind about what will be useful to decision makers, it can be hard to start from scratch with no intriguing initial result or pilot tool idea. To bring people to the table and start a dialogue, it sometimes takes a report, a finding, a puzzle, an event, or perhaps some interest in your area of expertise. The initial idea or thought that draws people together is only the start of the conversation; what ends up being usable may look very different.

5. Think about your objective

Because making research usable is a less familiar goal than producing peer-reviewed papers, it's important to articulate what it means to be successful. Define, or at least discuss, "success" with partners up front if possible. If sponsors expect research to be usable, they may require dedicated evaluation that demonstrates research was considered usable and/or used by stakeholders.

6. Conduct workshops with decision makers

Workshops with decision makers in a particular sector or region can promote dialogue about what types of information they need for better decision making, and what the research might provide to them. Such workshops are not science symposia, however. Take care when designing your agenda: Think about who is invited, who is asked to speak, and who is left to mostly listen. Which decision makers should be in the room: Do you invite the top representatives of an organization or the mid-level who are conducting the technical analyses? The right answer for you depends on the goals of the workshop. While the urge may be strong to "tell them what we know" from a science perspective; it is often helpful to have the decision makers lead off by talking about their decision contexts and initial interest in this research area. Resist "death by PowerPoint." Consider involving a facilitator, someone trained in helping you achieve the goals of the workshop, who can help design the meeting and keep it on track. Ultimately, make sure that the flow of information is two-way throughout the conception and planning of the workshop, and carried through to the design of the day itself.

7. Look for partners

Depending on your organization's stature with the decision makers you are engaging, consider partnering with regional organizations that already have credibility on the decision-making side. If you are new to a region or sector, such partnerships allow you to "borrow" credibility and facilitate greater engagement with the key decision makers more quickly than if you had to build such relationships from scratch.

Joint retreat of Western Water Assessment, the North Central Climate Science Center at Colorado State University, and the USDA Northern Plains Regional Climate Hub, at the Semi-Arid Grasslands Research Center, near Nunn, CO. Participants are looking at a field site that is part of NEON, the National Ecological Observatory Network. Photo: North Central Climate Science Center.

Boundary organizations (see "What is a Boundary Organization or Information Broker?" on page 9) may be good partners to reach out to.

8. Communicate your research findings in usable language and formats

Communication is not a substitute for producing usable science, but it's an important one to get right in stakeholder interactions. It is not sufficient to hand out reprints of journal articles or PDF slide decks of science talks—these do not speak clearly to people outside the research community. University press releases and news articles are often more accessible, but they tend to emphasize the novelty of findings and lack context for application, and so they are no substitute for carefully prepared summaries focused on potential uses of research for a specific audience. For higher-level decision makers, a short briefing document of one or two pages is helpful—anything longer will simply not be read. For technical staff and mid-level managers, a four-page briefing is often appropriate. The usual rules about communication apply: Know your audience; prepare short, relevant materials for presentations at events held by decision makers; think about conveying how the finding fits with previous research on this topic; and craft a clear take-home message for decision makers. CU Boulder has dedicated communication professionals who can help you craft your messages and review material. It is also worth considering sharing a draft of your findings or material with a trusted stakeholder partner to ensure that the language is relevant for their field.

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IMPROVING SEA-ICE FORECASTS

FLORENCE FETTERER of the National Snow and Ice Data Center (NSIDC), part of the Cooperative Institute for Research in the Environmental Sciences (CIRES) at CU Boulder, has spent her entire career thinking about sea ice. She first worked for the Navy investigating how sea ice affects operations, and then moved to CU Boulder to pursue a full-time research career. She kept up her connections with the National Ice Center (NIC) back in Washington, DC; NIC provides operational forecasts for NOAA and others. One question kept coming up in her conversations: What would it take to improve the accuracy of sea-ice forecasts? Existing methods were simply not very good at estimating concentrations of ice, and this shortcoming put ships and crews at risk. Florence kept asking the question, and finally the Naval Research Laboratory, where ice forecast models are developed, approached NSIDC to look into the question.

Florence and a team that included a NASA-based scientist worked to determine if better initialization fields for the sea-ice model would improve forecast accuracy. Because of her long-standing connection with the Navy, Florence understood the need for short-term forecasts (up to 5 or 6 days in advance) and was aware of the types of products that might be used or were being used already. Her team quickly came up with the idea of trying to blend some passive microwave satellite data with a human-calibrated daily sea-ice product from the National Ice Center. This combination produced a much better estimate of both daily ice extent and ice concentration, which are both needed for ship operations. The key to this collaboration was Florence's connection with the Navy's ice-forecasting group and the trust and knowledge that had been built. There was also a lot of communication during the project—quarterly (or more often) teleconferences between the research team in Colorado and the Naval Research Laboratory, and a lot of iteration.

NOAA's National Satellite Operations Facility at the Suitland Federal Center, in Suitland, Maryland. Photo: Wikimedia Commons/Stakhanov.

Florence's suggestions for producing usable research:

- Identify the operational needs that relate to your research area.
- Talk to people at the appropriate level in an external organization: For her, they were the analysts and forecasters. As Florence notes, "Sometimes they are somewhat hidden, but they are so important." Make an effort to go to them—don't expect them to come to you.
- Understand what is needed to build trust in the resulting improvement or product. In this case, the team partnered with the sea-ice modeling group at the Naval Research Laboratory, where the new method was tested extensively. The documented improvements in ice forecasts allowed the Naval Oceanographic Office to accept the new method for its operational ice forecasting model code. Until it was formally adopted, the team ran the testing and did research in non-operational mode.
- Partnerships with your stakeholders are key, in this case the U.S. National Ice Center and the U.S. Naval Research Laboratory.

For more information on this case: Data: https://nsidc.org/data/g10005; http://cires.colorado.edu/news/better-daily-sea-ice-forecasts-arctic-following-cu-boulder-led-innovation

NOAA's National Satellite Operations Facility at the Suitland Federal Center, in Suitland, Maryland. Photos: NOAA.

9. Survey your potential audience

If your group has access to someone with knowledge of how to construct effective surveys (e.g. social scientists), web-based surveys can help obtain a broad snapshot of decision makers' information needs across a region or sector. Surveys can't go into much depth and are not iterative, so you cannot rely on them for building a longer term, sustained dialogue with decision makers. Such iteration is often needed to converge on a practical and relevant way forward when co-producing science. Nonetheless, surveys have been used to provide an initial inventory of what types of needs for information exist in a region or sector.

10. Dedicate time and personnel

If resources permit, tasking one person in a research team with ensuring usability and making it a line item in a research plan or grant can help to ensure focus and continuity. If usability is a primary goal, not a secondary consideration, it is more likely to succeed. Boundary professionals (see "What is a Boundary Organization or Information Broker?" on page 9) are skilled at interacting with the broader network of decision makers and have a foot in the research world as well. It is rare to have resources for this within a research team, but it may be possible to connect to others within your organization or partner with outside organizations to access these personnel (see box).

PRACTICAL CONSIDERATIONS

Much of the guidance below comes from practical experience and "learning by doing." Each opportunity to make research usable will be unique, but we list here some of the common elements of our experiences building usable science:

- Trust and strong relationships are the basis of partnerships that create usable research—and they take time to build. Don't expect significant progress in the first engagements with decision makers.
- Set clear expectations of what is possible and what will be delivered.
- Reduce field-specific jargon and avoid acronyms in presentations and written materials.
- Recognize that for some, there may be no obvious incentive to taking time to build relationships and effective partnerships for making research usable. Disincentives, in fact, are common, for example when faculty are rewarded for publishing journal articles rather than engaging with stakeholders. If you are in a position to do so, look for ways to realign these incentives.
- Resist the temptation to leave the question of research use to the end of the project. While it may seem less important than the data and project itself, early engagement with those who might use research is much more effective than afterthoughts.
- Only some organizations and individuals will be able or willing to engage with researchers and spend time with a project. Focus on assembling a "coalition of the willing" rather than trying to coax reluctant participants.
- Everyone is busy. When a decision maker comes to a workshop or tries out a new data product, she or he is often setting aside other pressing work obligations. Be realistic about people's time commitments. And remember to be appreciative for their gift of time and engagement.
- Decision makers have many different considerations in decision making— science is just one. It is rare that a single research output has a direct and significant influence on a decision; more often, the use of research in decision making is diffuse and indirect. Manage your own expectations.

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OVERCOMING BARRIERS TO MAKING RESEARCH MORE USABLE AT CU BOULDER

Typical university and grant-making procedures disincentivize the production of usable research. Promotion and tenure guidelines for faculty at research universities, for example, emphasize peer-reviewed publications in high-impact journals. Funding program managers tend to prioritize research that pushes the frontier over research that addresses societal problems. Researchers who value usable science in the university but who are not tenure-track professors face difficult career paths and feelings of "not belonging." Students are often highly motivated to work on research that solves problems but can be discouraged from this path by the prevailing culture. Some of the ways these disincentives could be overcome at CU Boulder include:

- Offer small seed grants for "usable research" with the requirement that the proposal must include a primary non-academic partner who will engage in the research and advise on how it can be relevant to their organization.
- Promote graduate student internships that allow students to spend a period of time in a stakeholder organization, working on a project or participating in decisions.
- Create staff positions shared across units that serve as professional "boundary" agents to connect research with decision makers. This is distinct from a technology transfer office which primarily serves to commercialize research and establish companies.
- Start exchange programs to allow professors to embed in an outside organization for a period of time or allow practitioners to be on campus for a period of time, enabling the exchange of ideas and cross-cultural understanding. For example, the Center for Environmental Journalism at CU Boulder runs the Ted Scripps Fellowship that brings working journalists to CU for an academic year.
- Hire "Professors of the Practice." These are individuals whose life skills are in industry, government, or other spaces outside of academia but provide valuable teaching and research perspectives on linkages. Several other universities already do this such as the University of Arizona.
- Revise tenure and promotion metrics to encourage tenure-track professors to do research that connects with societal outcomes. This could include writing specific language into departmental guidelines that includes different metrics of impact for research, recognizes time spent building relationships, and promotes the value of addressing societal problems.

The 2015 Ted Scripps Fellows trek up Niwot Ridge to the CU Mountain Research Station located near Nederland, Colorado. Photo: Center for Environmental Journalism.

MONITORING INDUCED EARTHQUAKES

Like many Colorado Front Range residents, geophysicist and CU Professor **ANNE SHEEHAN** was surprised by a magnitude-3.2 earthquake on May 31, 2014. The epicenter was northeast of Greeley, CO, in the heart of an oil and gas extraction region, including waste water disposal. Unlike most others, Anne and her research group at CIRES were in a position to help figure out what was going on and produce science that could help inform decisions.

Anne did not have an ongoing research project in the area at the time, but after hearing about the quake, she and her students quickly deployed several seismometers around its epicenter and monitored for aftershocks and additional activity—with the permission of private property owners. Her team recorded data and produced local information that pinpointed one particularly high-volume well for wastewater injection. Using data from previous studies by others, they determined that rates of waste water disposal had recently increased.

She reached out to the Colorado Oil and Gas Conservation Commission, industry stakeholders, and the Denver Geophysical Society to present her findings. The response was mixed, reflecting the highly polarized societal dynamic around hydraulic fracturing, and the role of regulators, private industry, and local communities. Nonetheless, the COGCC found her results compelling and the well associated with the induced quake was temporarily shut down and modifications made to adjust the depth of the well.

CIRES/CU Boulder Graduate students Will Yeck and Jenny Nakai install a Seismometer near the epicenter of the Greeley earthquake.

The team's monitoring sites are still in place, and despite some early resistance from industry, industry users of the seismic data have become Anne's partners. One company representative even joined the advisory board for another of her research projects. The data from Anne's monitors can be accessed in real time on the internet, and industry contractors email her quickly when one of the monitors goes down. Anne has continued to talk with local government officials and now takes calls from county commissioners and others deciding on how to handle their own regulations and monitoring.

Anne's lessons from this usable-research case:

- It's worthwhile and rewarding to get involved, both personally and for CU Boulder as a whole. (Even when sometimes the going can get tough).
- People would be worse off without the data; both regulators and industry partners rely on its high quality.
- Connections matter. Anne had taught Geology to one of the participant's sons at CU Boulder, and she knew him by name. This helped pave the way for initial dialogue and allowed trust to build.
- Students think this project is fun and it helps them make connections for future jobs.

For more information: http://cires.colorado.edu/news/preventing-human-caused-earthquakes

Photo: Dr. Anne Sheehan displays her kit of solar-powered seismometers, used to measure earthquakes. Photo: AP/ Brennan Linsley.

CIRES/CU Graduate s tudent installs a Seismometer near the epicenter of the Greeley earthquake. Photo: David Oonk.

In 2014, then CIRES/CU Boulder graduate students Jenny Nakai and Matt Weingarten install a seismometer near the epicenter of the Greeley earthquake. David Oonk.

FREQUENTLY ASKED QUESTIONS

Would my usable research have less credibility within the scientific community?

For some, the idea of interacting with the intended users of research suggests the research is less "pure" or somehow contaminated if agents outside the scientific community influence the focus of research or its dissemination or communication. If the goal is to make research more usable, some level of interaction with the intended recipients is essential, with the explicit understanding that these interactions will shape the research or information products. This does not mean the research methods that create knowledge are any less robust or rigorous. As an expert in your field, you can ensure that the same standards for scientific credibility and validity apply. The interaction just means that the research process and information dissemination is sensitive to and shaped by what is most valuable to supporting decision making.

But isn't this what consultants do?

While consultants are in the business of studying, synthesizing, and modeling particular questions of interest to governments and business, they often have a narrow mandate with a scope already predetermined by the client (i.e. needs are already well known). So consultants generally have little room to co-produce research, to bring in unrequested knowledge, or to change the premise of the question being asked. On the other hand, consultants can be valuable partners in group processes seeking to make research usable, because they are often very familiar with client needs in a given sector.

But won't decision makers who are interested in my work be able to find it themselves and use it?

It turns out the that idea of putting research out in journals for others to take up and use is at best inefficient, but more often, simply doesn't work to get relevant, timely, and useful research into the hands of decision makers. Without some degree of dialogue (whether minimal in the case of post-project pathway, or intensive in the case of the co-production pathway), it's unlikely that a research paper is going to meet the needs of decision makers. Study after study has shown that research conducted or disseminated in the absence of awareness of the problems faced by decision makers and their timelines, scale needs, language, and accessibility requirements, etc. is generally not usable. Please see the "For Further Reading" section below for more information and background.

CONCLUSIONS

In sum, there are a range of pathways and steps to help make research more usable. CU Boulder provides a wealth of examples to learn from and build upon. Above all, we argue that it is important to be deliberate about engaging the tools and resources needed to make research more usable. This process can unlock so much more potential for improved use of research in societal decision making across a range of scales and sectors. It's also clear that experimentation with different approaches is both valuable and needed: There are so many possibilities and routes to achieve more usable science.

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Available online at: http://wwa.colorado.edu/publications/reports

SNOW SCIENCE FOR AVALANCHE SAFETY

Hydrologist **JEFF DEEMS** epitomizes the concept of doing what you love—he is both a backcountry skiing enthusiast and a snow researcher. From his love of winter sports and recreational knowledge of the danger of avalanches, Jeff came upon an idea from his research that he thought might be of interest to ski resorts and road managers in Colorado. Avalanches occur on steep slopes when heavy snowfall and wind drift has accumulated and the buildup is released suddenly, triggered by a number of possible disturbances, including heavy snowfall, the weight of a skier, or wind-driven snow. Ski resorts and mountain road maintenance crews often use explosive charges to preemptively trigger avalanches under controlled conditions to prevent large buildups from posing a hazard to skiers or drivers below.

Jeff had been working on a lidar-based (laser scanner) method that can map patterns of snow depth with a much higher spatial resolution and accuracy than ever before, and he thought it might help resorts and others manage avalanche risk more effectively. Knowing the snow depth at precise locations would allow crews to trigger avalanches in the right place, and might reduce the risk of injury to personnel. Through prior personal and professional connections, he got in contact with staff at the Arapahoe Basin Ski Area, including the snow safety director and someone on ski patrol. He saw a chance to try out his idea in practice and see if it was valid from the point of view of practitioners. From the beginning, he had some credibility with the ski area because he knew what questions to ask and used the right language because of his long-time ski passion, his experience as an avalanche educator, and prior research experience. "They could tell I understood what they were saying," he says. It also helped that avalanche science had a long history of connecting research and practice, including combined researcher-practitioner conferences.

Adam LeWinter (CRREL) and Jake Ziemski (Arapahoe Basin) use near-realtime snow depth maps to plan avalanche control explosives targets. Photo: Jeff Deems.

Jeff got a chance to test out the usability of his research in a particular season with the ski resort. He worked with the Arapahoe Basin Ski Area and their snow safety team to create a change-in-snow-depth map. This identified some of the usual targets for avalanche control, but also revealed some locations that they wouldn't have otherwise tried. They also were able to support decisions not to apply explosives—an important hazard- and cost-reducing use case. Jeff did a lot of work with the ski area in the beginning to demonstrate the data in person, fine tuning and honing it so that the ski resort personnel knew exactly what went into it and how it could work as part of their operations. Now they are able to look at and apply the products on their own. The data are now used for planning the opening of new ski terrain. They are also being used by the Colorado Department of Transportation to better locate permanent gas-based "exploders" to remotely trigger avalanches in the most hazardous paths.

Jeff's lessons for making research usable:

- Get some sort of practical experience in the field or industry you want to work with, even spending time working there if you can.
- Find practitioners who have an open attitude to collaborating with researchers.
- Make time for repeated interactions with users of the data, especially when piloting the data or tool.
- Ask the users: What data are relevant? What is the timing of data needed? Do the data mesh well with the operations of the user, and if not, how can they be adjusted to work better?
- It's important to not enter into an interaction with an assumption of how users "should" use the research idea you have. Be open to the different ideas practitioners might have about use.
- Early successes with a group can lead to more interest and a "snowballing" effect where other uses and interests are identified.

Researchers use this laser-scanning (lidar) instrument to map snow depth at very high resolution. Photo: Jeff Deems.

Jeff Deems readies the laser scanning system to map the East Wall area at Arapahoe Basin. Photo: Jeff Deems.

Western Water Assessment

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