NASA Western Water Applications Office &
Western States Water Council

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Workshop Report
Technology Transfer for Water Management in the Western U.S.

August 7-9, 2019
Irvine, CA

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EXECUTIVE SUMMARY

The Western States Water Council (WSWC) and the NASA Western Water Applications Office (WWAO) hosted a joint workshop on technology transfer for water management in the Western U.S. The goals of the workshop were to understand how different agencies approach the technology transfer and research to operations (R2O) process, identify best practices, and discuss existing barriers to successful technology infusion into operational water resource management systems at the state and federal level. The workshop took place August 7-9, 2019 in Irvine, CA. Key outcomes of the meeting include the following:

- U.S. Rep. Grace Napolitano provided opening remarks for the workshop, where she highlighted the critical value of water data and the importance of collaboration between state and federal agencies in working to advance the use of water data in water management, planning and policy.

- A total of 33 participants (including remote participants) were part of the workshop. They included principal investigators and project teams supported by NASA (Cyanobacteria Assessment Network, Evapotranspiration for Western States, Evaporative Stress Index, the Airborne Snow Observatory, Satellite-based Snow Water Equivalent in the Sierra Nevadas, and Fallowed Area Mapping) as well as representatives from federal (USGS, NOAA, USBR, EPA) and state (CA, WY, OR, NE) agency partners.

- One main outcome of the meeting was the consensus that successful transitions of new applications and new technologies into operations require careful planning, effective communication within and across institutions, resources and considerable time investments. In addition, there was broad agreement that significant lead time is often required to allow for identification of financial and technical resources to sustain operational use of new data, information and tools.

- The meeting included remarks from U.S. Rep. Napolitano and discussions during presentations and breakout groups about key opportunities to develop best practices and streamline the technology transfer process.

- For example, one key set of best practices that emerged revolved around the the importance of building trust and establishing clear lines of communication between the research and operational institutions. The conversations led to defining two key components of trust-building. The first aspect is purely technical. It requires effectively demonstrating that the proposed application meets the end user's needs

in terms of accuracy, format, resolution, latency, metadata and documentation. The second aspect of building trust involves developing sustained, productive and mutually-beneficial relationships with the partner operational agency. The best practices presented here span both the technical as well as the relational aspects of cultivating trust.

- This workshop served as a first step in developing a broader community discussion around R2O in western water management. Many of the best practices and lessons learned described in this report represent starting places for action within the WWAO, WSWC and our colleagues' institutions.

- Effective implementation of the best practices that emerged from this workshop will require sustained investments of time, resources and transition planning. In recognition of this, the WSWC and the WWAO proposed continuation of discussions begun at the workshop through a series of semi-annual or annual workshops.

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INTRODUCTION

NASA's Western Water Applications Office (WWAO) was chartered to work with state, federal and local water resource management agencies and other partners to develop new applications of NASA data and technologies to advance water resources management in the Western U.S. WWAO is currently working with state and federal water managers and NASA scientists to co-develop high-impact projects with the objective of delivering applications that have sustained operational use in water resources management.

The Western States Water Council (WSWC) is a government entity of representatives appointed by the governors of eighteen western states. Since its creation, through adoption of a resolution at the Western Governors' Conference in 1965, the Council has striven to fulfill its chartered purposes. While the emphasis and focus of the Council has changed over the years, that essential principle remains: to foster cooperation among it member states, and provide a forum for discussion of a broad spectrum of water resource challenges facing the West.

In recognition of the complex challenges associated with the research to operations (R2O) process, particularly for water management in the West, WWAO and WSWC co-sponsored a workshop focused on this topic. The workshop took place August 7-9, 2019 in Irvine, CA. Appendix I includes the full detailed agenda for the meeting.

The workshop participants included principal investigators and project teams supported by NASA as well as representatives from federal and state agency partners. The NASA-supported projects invited to participate were selected on the basis of their success in the transition process. Two of the projects already completed a successful transition, including the Cyanobacteria Assessment Network (CyAN) project and the Evaporative Stress Index (ESI) project. The other projects that presented were in the process of the transitioning to operational use. These included the Airborne Snow Observatory (ASO), Evapotranspiration Mapping for Western States, Fallowed Area Mapping, and work to advance operational satellite mapping of snow water equivalent in the Sierra Nevada. State partners represented include the California Department of Water Resources, Oregon Department of Environmental Quality, Oregon Water Resources Department, Nebraska Department of Natural Resources and the Wyoming Department of Water Resources. Federal partner agencies represented in the workshop included the U.S. Geological Survey (USGS), the National Oceanic and Atmospheric Administration's National Weather Service (NOAA NWS), the U.S. Bureau of Reclamation (USBR), and the Environmental Protection Agency (EPA).

The overarching goals of the workshop were to:

1. Begin building agency partnerships and a network of experts to facilitate application transition from NASA for water resources management decision support;
2. Discover and document best practices for successful application transition; and
3. Identify current barriers to technology transfer and establish pathways to overcome those barriers.

Addressing these three workshop goals enabled us to make progress toward ensuring that NASA's valuable scientific resources can be made available to our partners in a sustained way, that maximizes the utility and public benefits of NASA science and technology.

RESEARCH TO OPERATIONS CHALLENGES & BEST PRACTICES

In this section of the report, we attempt to capture the challenges and best practices that emerged as central themes across multiple projects in their R2O process. To start the discussion, Session 1 featured speakers from various NASA offices and programs, including the Applied Sciences Water Resources Program, the WWAO, and the Office of International and Interagency Relations. The presentations covered emerging NASA technologies and capabilities that show high potential for benefiting water management as well as the best ways to form partnerships with NASA and other organizations. Among the presentations from Session 2 (Perspectives from Federal Partners), speakers highlighted a variety of best practices for R2O in their respective agencies. Additional best practices and challenges emerged in Sessions 3A, 3B (Perspectives from NASA-funded Projects) and Session 4 (Perspectives from State Partners). Note that we do not present an exhaustive list of the best practices and challenges that emerged. Instead, we compiled the list of based on the commonalities that we heard across many of the discussions.

A. <u>Understanding partner needs</u>

- Our state partners in particular emphasized that most state agencies are only willing to take on proven approaches that address a real need they have.
- Although this did not arise in the projects that presented in the workshop, multiple researchers at the workshop agreed that in general, a common issue they have seen in applied science projects is when researchers approach a stakeholder with a specific model or application that was already built. Often, this does not give end users enough space to fully articulate what they truly need and would value. This situation arises most when researchers fail to take the time to fully understand the problem, or are too attached to one particular solution.

- A good indicator of when a project meets a key need is that the end-users are investing resources (financial or personnel) into the partnership. This point was made by both NASA P.I.'s as well as by our federal and state partners.
- Most of the NASA Applied Science P.I.'s at the workshop underscored the importance of moving beyond the mindset of "a technical solution looking for a problem" by being curious about the decision-making challenges and being open minded about the solutions.

B. <u>Importance of Structure and Planning</u>

- Transition plans are especially important when the technology transition occurs between two separate agencies or organizations. In fact, many of the presentations from federal partners highlighted the flexible and often semi-structured aspects of the technology infusion process within the same umbrella agency from a research arm to an operations arm.
- Technology transfer across separate organizations raises additional challenges. For instance, multiple project teams that presented in Session 3 stated how challenges in financial planning, coordination between the water resource partner and centralized IT departments, assessment of information technology (IT) infrastructure or fully understanding the partners operational environment presented key challenges to a smooth transition process.
- NASA Applied Sciences projects also spoke of the value of sharing lessons learned between projects, support in engagement with agency management, and the potential value of training on various transition pathways (e.g., differences associated with a transition to the commercial sector versus to a state or federal agency).
- One possible approach to addressing the gap in knowledge and expertise in R20 could involve providing NASA Applied Science projects "R20 best practices trainings" as well as access to people with experience in the R20 process.
- The project teams highlighted that if they were to accept support from an individual or team who has experience in R20, this person or group would need to be thoroughly embedded in the entire project, not just in the last year or two when the transition takes place.
- For transitions happening from NASA to an external end user, there is a need to have clarity about the benefits and drawbacks of various transition pathways. For example, if the transition is to the private sector, state agency limitations on sole-source contracts would need to be considered in funding models.
- Application transition plans should dedicate an entire section to allocation of financial resources for each step of the process from both institutions. It is also vital to involve

upper management at the partner agency and NASA in this discussion early in the process.

- It is critical to be realistic about the timeframe of the transition. If the need is great enough, then the stakeholder organization will be much more likely to speed up the process. However, a general consensus emerged that an appropriate amount of time to allocate to transitions is at least two years. Thus, project teams need to accept that transitions take time and develop their plans appropriately.
- For operational state and federal agencies, finding in-kind financial resources to support a transition is difficult. However, allocating staff time is much easier to do – especially when the proposed project clearly fills a need and demonstrates that training for staff will enable them to sustain measurements.

C. <u>Communication Within and Across Institutions</u>

- The first set of communication best practices presented here arose in communications within institutions, and projects agreed that it was important to establish the following as early as possible in a project:
  - Consensus on what the pathway forward should be, including buy-in from agency management and IT staff.
  - Clear agreements on who would play what role in the transition.
  - Identification and mitigation of key risks, such as planning for how to adjust when key personnel retire or leave.
- When a transition happens over two or more partner organizations, the communication and transparency across these institutions is of critical importance. The key best practices reported by many of the projects with multi-institutional transitions include:
  - Understanding partner's capabilities, bandwidth and financial resources.
  - Elevating the transition to upper management in both the research and the end user organizations as early in the project as possible. Specifically, once the technical teams demonstrate that the application meets end users needs and that it is financially as well as technically feasible to transition, upper management need to become a part of the planning process. In multiple cases explored at the workshop, these transition discussions between the partner organization and/or the research organization did not happen early enough or did not engage senior management early enough.
  - It is important to formalize partnerships in writing via multi-lateral memoranda of understanding (MOUs) or other flexible agreements.
  - There is a need for more flexible partnership agreements, and NASA Space Act Agreements often are not sufficiently flexible especially for partnerships with state agencies.

- Sustained engagement after the initial transfer plays a critical role in long-term adoption. For our partners, this would typically take the form of casual but on-going follow-up conversations where the researchers would ask the end users how useful the application has been so far and what improvements could be made. Sometimes the conversations would lead to additional de-bugging, testing or increased functionality. Other times, the feedback might not be implemented right away, but instead captured and later developed as a separate project.

D. <u>Building Trust</u>

- The first aspect of trust building that emerged in many of the presentations involves ensuring that the project meets all technical requirements. Our state partners emphasized that their agencies can't risk investment of extra resources in experimental, unvalidated products.
    - To conduct an effective validation effort, research teams must understand the partner organization's accuracy requirements. This way, the project can use the results from the validation and uncertainty quantification studies to determine if the application as currently implemented can feasibly fill the end user needs and, if not, in what ways and to what extent the application or model can be modified to meet the requirements.
    - Validations and uncertainty quantification must be rigorous and peer-reviewed.
    - Validation studies must also be presented in an understandable and transparent way to the end users and decision-makers. For this reason, federal and state partners highlighted the need to walk through the results with the project partner, ensuring that the results meet the original accuracy requirements.
    - Open source code greatly improves transparency.
    - In Session 2, the presentations from our federal partners shared a common theme around the research arm serving the function of curation and vetting before any infusion of new technology into the operational arm of the organization would occur.
- The second aspect of building trust revolves around relationship building. The projects featured in the workshop all invested significant effort in strengthening the relationships with project partners. For this reason, few challenges emerged in this domain from the specific projects that presented in Sessions 2 and 3. The following key best practices were identified:
    - The way that the research team approaches the initial discussion with the partner organization creates an important first impression. To avoid overselling a capability, it is important to be transparent about the strengths and limitations of

remote sensing data, hydrologic models or other tools the project proposes to explore.
    - Finding a strong advocate or "champion" within the partner organization is key, particularly when the R20 process occurs in a separate agency from the research organization.
    - Many of the presentations from our Federal partners highlighted how long-standing relationships between individuals in the research branch and the operational branch of the agency greatly enhanced the ease and effectiveness of the R20 process. Such relationships perhaps emerge more easily when all parties work for the same agency.
    - However, building strong relationships between researchers and end users in separate organizations can also occur. A suggestion that NASA PI's and Federal partner researchers shared is to avoid overselling the capability by being conservative about modeling/data capabilities.

E. <u>Capacity Building</u>

- Similar to categories on building trust and understanding partner needs, most of the projects in our workshop attributed a big part of their success to how they anticipated possible challenges associated with capacity building and designed their trainings in such a way that potential barriers could be avoided.
- There is a clear need to establish a sense of respect, partnership and even informality so that end users feel comfortable asking any and all questions. One way to establish this sense of comfort in trainings is through encouraging dialogue and avoiding structures that are too formal or one-sided (i.e. lecture style). Another effective approach is to plan meals or other informal activities that the group can share.
- In federal agencies, for instance, the strong sense of trust already established between the research to operations arms allows for a level of informality in the way that communication, capacity building, and end user feedback on the application occur. This establishes a strong foundation and sense of safety that is conducive to learning and adoption of new innovation.
- Design a capacity building program catered to the audience: make trainings accessible to users by understanding their level of technical experience.
- One key question that emerged in this discussion is: How do we move workforce development at all levels of government and all levels of industry towards the direction of being able to use new technology/modeling/data/applications? An opportunity was identified to develop additional training resources on applications of satellite data specifically for water resources managers at state and federal agencies.

F. Roles and Careers for Researchers in Applied Science

- End-user/stakeholder integration is widely regarded as both a key feature and core challenge of applied science research. Applied integration is often considered critical to the success (or failure) of R2O. Yet most researchers do not have training, time, nor an incentive to undertake the challenges of a transition. Those who do often learn as they go because there is currently no set of best practices, guidelines or structure to help the project team map out a plan.
- Given this importance, the workshop participants called to attention the need for the emergence of new roles, skill sets, and career paths for "applied science integration research specialists/experts." However, at present these key skill sets are vague and applied work is not strongly rewarded in a research career (no publications, no recognition).
- The motivation and therefore success rate of R2O transitions may increase if individuals partaking in applied science integration and transition roles were more highly valued in the research community. Research institutions can address this issue through training programs, giving awards (monetary or not), and other forms of recognition for applied scientists who effectively span the research to operation gap.
- If we do expect scientists to be responsible for transition of their application, then they need training and a set of best practices to follow. The WWAO Applications Transition Plan aims to address the gap by: (1) characterizing the professional roles, responsibilities, and functions of applied integration specialists/scientists; and (2) analyzing their skills, competencies, and capabilities.
- A key reason to be in the applied science field is by seeing the real impact of how research can help partners in making increasingly challenging and complex decisions. The WWAO Applications Transition Plan and other structured approaches that aim to support applied research teams in achieving transition have an opportunity to highlight the real impact a successful transition can have. Any applied science honors and rewards established to recognize success in R2O also can be designed to emphasize the tangible beneficial impact that a transition made on the targeted group of end users, as well as other environmental and societal benefits that arise.

POSSIBLE FOLLOW-ON ACTIVITIES FOR WWAO

The WWAO would be interested in exploring some or all of the following possible actions and activities:

- Compile a complete list of best practices and lessons learned from SPoRT (Short-term Prediction Research and Transition Center), NOAA NWS, the USBR Challenge Program, and other sources through surveys and in-depth informational interviews.
- Survey current project partners to obtain a better understanding of required lead times and procedures for reviewing new data / tools and allocating financial resources to new programs or data systems.
- Develop training programs for NASA PIs and project partners on best practices for technology transfer.
- Continue to organize regular workshops on the topic of R2O for water management in the Western U.S.

SYNTHESIS & NEXT STEPS

Addressing the barriers and implementing the best practices that emerged from this workshop will involve institutional changes in terms of the amount of time, resources and planning allocated to R2O. WWAO has an opportunity to embed these best practices into many aspects of what we do as a program office, including the development of requests for proposals and solicitations, the processes formalizing inter-agency agreements, and the way that successful transitions are recognized and celebrated within and outside of NASA. These suggestions are particularly relevant for the NASA Applied Sciences Program (ASP) within the Earth Sciences Division, as R2O is one of the main indicators of success for NASA ASP.

The best practices identified in this workshop fall within the categories of: (A) understanding partner needs; (B) careful planning; (C) communication; (D) building trust; (E) capacity building; and (F) educating the next generation of applied scientists. All of these aspects of R2O play critical roles in achieving successful transitions. The two areas that presented the most difficulties specific to the NASA Applied Sciences projects fell into category (B) planning and (C) communication—both within the research organization and across organizations to the end users. To that end, a key next step from this workshop for the individual NASA Applied Sciences projects that have not transitioned yet involves translating the general comments along the lines of “transitions take too long” and “we need more resources to make the transition happen” into a specific plan and demonstration of how additional resources could be used to ensure a successful R20 pathway. In this process, the project teams must be realistic about the timeframe and plan for no less than two years, keeping in mind that sustained engagement after the transition is needed. Many NASA project teams as well as our federal partners emphasized that the “post-transition” engagement is critical for addressing unexpected questions, making

ongoing fixes or software updates, and ensuring that the end user organization is fully equipped to maintain the application. Often these conversations happen over the span of a year or more.

The main finding of the workshop is that improving R2O in water management requires significant investment from both research and operational institutions. Changes within NASA will not be enough to ensure increasing rates of success in transitions. Partner agencies must also make R2O a priority. Drought, declining groundwater levels, growing demand for water across many economic sectors, and climate change together create a critical need for advances in our collective ability to monitor and manage water resources in the western U.S. In response to this, the WSWC and the WWAO will work together to build a community aimed at addressing these challenges. A first step in this direction involves establishing a series of semi-annual or annual workshops dedicated to this topic.

Acknowledgements

WWAO and WSWC would like to thank all of the attendees for their attendance, insight, and active participation.

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Appendix I – Detailed Workshop Agenda

Wednesday, August 7, 2019					
Time	**Session**	**Title**	**Speaker**	**Affiliation**	**Moderator**
12:30 PM		Registration			
1:00 PM		Opening Address from Congresswoman Grace Napolitano	Congresswoman Grace Napolitano	U.S. Congress	
1:15 PM		Welcome & Workshop Goals	Tony Wilardson, Jeannine Jones	WSWC	
1:30 PM	**Session 1**: Perspectives from NASA	Overview of NASA Applied Sciences Program	Brad Doorn	WWAO	Savannah Cooley
1:40 PM		What is the NASA Western Water Applications Office (WWAO) and how does it support NASA's role in technology development?	Indrani Gracyk	NASA WWAO	
1:55 PM		NASA Earth Science applications with high potential for technology transfer	Savannah Cooley, Forrest Melton	NASA WWAO	
2:10 PM		NASA Interagency Partnerships	Laura Delgado Lopez and Jolene Meidinger	NASA HQ	
2:30 PM		~~~~~~ BREAK ~~~~~~			
3:00 PM	**Session 2**: Perspectives from Federal partners	Perspectives from Federal partners: NOAA	Jonathan Rutz	NOAA	Forrest Melton
3:30 PM		Perspectives from Federal partners: USGS	Mindi Dalton	USGS	
4:00 PM		Perspectives from Federal partners: EPA	Roger Gorke	EPA	
4:30 PM		Perspectives from Federal partners: EPA / CyAN project	Erin Urquhart	EPA	
5:00 PM		Perspectives from Federal partners: USBR	Kenneth Nowak	USBR	
5:30 PM		~~~~~~ ADJOURN ~~~~~~			
5:30 PM	**Reception in the Atrium**				

Thursday, August 8, 2019					
Time	**Session**	**Title**	**Speaker**	**Affiliation**	**Moderator**
9:00 AM	**Session 3 A:** NASA Applied Science Projects	Evaporative Stress Index	Chris Hain	NASA MSFC	Forrest Melton
9:30 AM		Airborne Snow Observatory	Judy Lai-Norling	NASA JPL	
10:00 AM		Cyanobacteria Assessment Network (CyAN) Project	Megan Coffer	EPA	
10:30 AM		~~~~~~ BREAK ~~~~~~			
11:00 AM	**Session 3 B:** NASA Applied Science Projects	Evapotranspiration for Western States	Justin Huntington	DRI	Indrani Gracyk
11:20 AM		CA Fallowed Lands Mapping	Forrest Melton	NASA WWAO	
11:40 PM		Satellite mapping of snow water equivalent for CA DWR	Noah Molotch	U of CO, Boulder	
12:00 PM		~~~~~~ LUNCH ~~~~~~			
2:00 PM	**Session 4:** Perspectives from State partners	Perspectives from State partners: Wyoming	Charlie Ferrantelli	Wyoming	Jeanine Jones
2:15 PM		Perspectives from State partners: Nebraska	Jesse Bradley	Nebraska	
2:30 PM		Perspectives from State partners: Oregon	Jordan Beamer	Oregon	
2:45 PM		Perspectives from State partners: California	Mike Anderson	California	
3:00 PM		Perspectives from State partners: Oregon DEQ	Aaron Borisenko	DEQ	
3:15 PM		~~~~~~ BREAK ~~~~~~			
3:30 PM	**Session 5:** Synthesis of lessons learned	Breakout group discussions	ALL		
4:30 PM		Report-out from group discussions			
4:45 PM		Discussion			
5:00 PM		~~~~~~ ADJOURN ~~~~~~			
Friday, August 9, 2019					
Time	**Session**	**Title**	**Speaker**	**Affiliation**	**Moderator**
9:00 AM	**Session 6:** Thinking Outside the Box	Forecast Rodeo Symposium	Dave Raff	USBR	Tony Willardson
9:20 AM		Water Data Exchange (WADE)	Adel Abdallah	WSWC	
9:40 AM		NASA Small Business Technology Transfer	Mark Davidson	NASA STTR	
10:00 AM		~~~~~~ BREAK ~~~~~~			
10:30 AM	**Session 7:** Appropriations 101	How to communicate with Congress	Tony Wilardson	WSWC	Jeanine Jones
11:00 AM		Discussion	ALL		
11:20 AM		Closing Comments			
11:30 AM		~~~~~~ ADJOURN ~~~~~~			

Appendix II – Glossary of Acronyms

ASO	Airborne Snow Observatory
ASP	Applied Sciences Program
CyAN	Cyanobacteria Assessment Network
DOI	Department of Interior
ESI	Evaporative Stress Index
DWR	Department of Water Resources
ET	Evapotranspiration
GSFC	NASA Goddard Space Flight Center
IT	Information Technology
JPL	NASA Jet Propulsion Laboratory
MOU	Memoranda of Understanding
NASA	National Aeronautics and Space Administration
NASA ASP	NASA Applied Science Program
NOAA	National Oceanographic and Atmospheric Administration
NOAA-NWS	NOAA - National Weather Service
PI	Principal Investigator
R20	Research To Operations
SPoRT	Short-term Prediction Research and Transition Center
SWE	Snow Water Equivalent
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WSWC	Western States Water Council
WWAO	Western Water Applications Office

Appendix III – Workshop Participants and Contributors

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