WEATHER READY NATION - O2R2O WORKSHOP REPORT

Building a Weather Ready Nation by Transitioning Academic Research to NOAA Operations

Abstract

Report of a workshop designed to inform and strengthen engagement between operational and research communities as an activity of NOAA's Weather Ready Nation Initiative.

Table of Contents

Building a Weather-Ready Nation
by Transitioning Academic Research to NOAA Operations

Report of a Workshop held November 1-2, 2017
College Park, Maryland

Executive Summary

This report is a summary of discussions and recommendations from a workshop jointly convened by the National Oceanic and Atmospheric Agency (NOAA) and the University Corporation for Atmospheric Research (UCAR): *Building a Weather Ready Nation by Transitioning Academic Research to NOAA Operations*. The meeting was held Nov 1-2, 2017 at NOAA's National Centers for Weather and Climate Prediction (NCWCP), in College Park, Maryland.

The workshop was designed to inform and strengthen engagement between research and operational communities, as an activity of NOAA's *Weather Ready Nation* *(WRN)* initiative. WRN is a NOAA-wide activity, focused on improvement of weather and climate services. Its goals may be summed up in three key words: *readiness*, *responsiveness,* and *resiliency*.

This initial workshop focused on R2O applicable to forecasting, unified modeling goals, observations, and related operations of the National Weather Service, as mandated by the 2017 Weather Research and Forecast Improvement Act (P.L. 115-25). Presentations about services and practice included available NOAA mechanisms and opportunities for funding; policies and procedures; and the current "state of the state" supporting transitions between *operations to research (and back) to operations*. The full acronym is *O2R2O*; each activity feeds the other. The overall goal is to seek the best methods to enable and support readiness, responsiveness, and resiliency *within* the dynamics of O2R2O, to best utilize both the research and operational capacities of the nation.

Specific goals of the workshop included:

- informing attendees about NOAA programs for transition, and the policies governing transition of research to operations (R2O);
- promoting best practices for transition of research to operations;
- gathering input, suggestions, and identification of constraints or issues from a mixed community of researchers and operational personnel.

The initial day included multiple presentations of relevant NOAA policies and developments supporting O2R2O; successful examples; National Weather Service (NWS) and Office of Atmospheric Research (OAR) collaborations; and other NOAA-wide mechanisms supporting the integration of research with operations. Presentations are available from the event website.

Key Input

The discussions led to several strong suggestions on the participation of the academic community in NOAA R2O activities:

1. The academic community has a different rewards system from that of an operational organization. Scientific publication is critical for the career advancement of university professors and students. Therefore, the academic community will be much more interested in research that can lead to publication. Consciousness of this on NOAA's part is strongly encouraged.
2. The availability of computing resources is critical for successful R2O in weather and climate modeling. Given the limited NOAA computing resources and the challenges of obtaining security clearance to use NOAA computing facilities, an alternative solution is needed. Making NOAA operational models and data, and computing resources available through the cloud is an attractive solution.
3. The academic community cannot work for free. Therefore, appropriate funding to support their participation in R2O is critical. Good examples include the Hurricane Forecast Improvement Project (HFIP), Next Generation Global Prediction System (NGGPS), and Joint Technology Transfer Initiative (JTTI) announcement of opportunities.

Priorities, Gaps, Challenges

The workshop identified areas that need to have greater *priority* for the transition of research to operations, and existing *gaps* and *challenges* to both the academic research community and operational environments in O2R2O. The areas where existing research has not yet transitioned into operations, and where challenges are most pressing, are listed below.

Responses generally fell into two categories, with some overlap: *technical issues*, and *process issues*; with *social science issues* threading throughout all the discussions and outcomes. The rise-to-the-top issues included:

- *Data assimilation* techniques, infrastructure, and support appear as priorities, gaps, and challenges.
- *Modeling* improvements, especially in transition of existing research (e.g., physics package integration) are a priority, gap, and challenge.
- Critical gaps in *high performance computing* needs of both the research and operational communities was a high priority issue. For the research community, lack of response in access to HPC accounts from NOAA was cited repeatedly. For operational needs and support, gaps in HPC availability for effective data assimilation were also noted.
- The academic research community does not have strong understanding of NOAA *Readiness Levels* and how their research foci map to these.
- *Perceptions* include NOAA O2R being focused on narrow targets; a pace of implementation that is not agile, is too slow and not in sync with research goals and process; and a strong sense that the research community is not well incentivized to participate in collaborative activities with operational communities. A key incentive for

advancement in research communities is publication; this requirement for academia does not seem to be well recognized or supported in collaborative R2O opportunities.

- NOAA funding opportunities are seen as limited in the necessary resources to support critical research. Good examples of effective but underfunded RFPs include some of the opportunities detailed at this meeting: a) NGGPS: Next Generation Global Prediction System; b) S2S: Seasonal to Sub-seasonal (Weeks 3-4) forecasting improvements; HFIP: Hurricane Forecast Improvement Project. It would be helpful for NOAA to provide the community some statistics about its funding levels and success rate trends, in order to effectively develop a funding stream supporting 02R20.
- The research and operational communities are eager to continue to improve and foster productive O2R20 collaboration, and to continue to meet and provide opportunities for communication, understanding, and the expansion/creation of effective intersections.

Workshop Structure and Process

The first day of the workshop provided a series of overview presentations from conveners and NOAA personnel on current status and available opportunities, followed by sessions from both academic researchers and NOAA representatives involved in the transition of research to operations, to applications, or to commercial use (R2X). Topic areas included:

- Observations and instrumentations
- National Centers for Environmental Information (NCEI) production suite
- Social science aspects of NOAA operations
- R20 in satellite observation, data assimilation, and in weather modeling
- National Water Model
- Roles of NOAA laboratories, Cooperative Institutes, and Cooperative Science Centers in R2O
- R20 in wave models and climate
- Support of operational systems to the research community:
    - NOAA Developmental Testbed Center (DTC)
    - Multi-agency-supported Joint Center for Satellite Data Assimilation (JCSDA)

The second day of the meeting was entirely focused on the feedback/input aspect of the workshop. 106 attendees were split into four break-out groups to identify issues and challenges and provide recommendations. Groups were presented with four key questions for consideration, shown below.

The groups spent a half-day discussing and formulating their responses and reported back with overviews of their agreed-upon priorities and issues, accompanied by time for questions and general discussion across the entire group of attendees.

Questions

1. From your or your organization's point of view, what area of weather has matured research that has not transitioned to NWS operations? (For example, new observational techniques, numerical modeling techniques, data assimilation techniques, etc.) Can you list two or three R2O priorities that you think NOAA should focus on in the next five years?
2. What are some of the biggest gaps in current weather forecasting that NOAA needs to focus on transitioning in order to fill these gaps in the next five to ten years?
3. From the perspective of your organization, what is the biggest challenge your organization faces in transitioning research to operations, other than funding issues?
4. Testbeds play a crucial role in transitioning research to operations. Do you know anything about the NOAA testbeds? Are the current testbeds serving the intending purpose? Are they readily accessible to the academic and private sector?

Day 1: Presentations and Discussions

Session 1 – NOAA Transitions – welcome remarks, overview, status, and opportunities

Contributors:

- *John Cortinas - Director of Office of Weather and Air Quality (OWAQ), of the NOAA Office of Atmospheric Research (OAR); co-chair of the workshop*
- *Gary Matlock - NOAA Deputy Assistant Administrator for Science; Director of the Office of Policy, Planning, and Evaluation in the Office of Oceanic and Atmospheric Research (OAR).*
- *Anthony Busalacchi – President of the University Corporation for Atmospheric Research (UCAR).* UCAR is a consortium of 117 member universities with atmospheric and climate science programs, and operates the National Center for Atmospheric Research (NCAR).
- *Mary Erickson – Deputy Assistant Administrator, National Weather Service (NWS)*
- *Hendrik Tolman, Senior Advisor for Advanced Modeling Systems; Office of Science and Technology Integration (STI), NWS*
- *Derek Parks, Technology Transfer Program Manager, NOAA Technology Partnerships Office*
- *Christopher Hedge, NOAA/NWS Federal Program Officer*

John Cortinas, OAR *Director of the Office of Weather and Air Quality (OWAQ),* and co-convener with UCAR, provided welcoming remarks reaffirming the goals of the workshop: to strengthen engagement between the academic research community and NOAA operations; to hear from the community how best to accomplish R2O; to find out what works, what doesn't, and to provide ideas for improvement. Cortinas emphasized that a top priority within NOAA is on the *process* of transition. The aspirations for this workshop are for a two-way communication exchange that enables getting a sense for the actual experiences of those who have tried and not succeeded in transitioning research, and for NOAA to provide information on its internal activities that can foster transition.

Gary Matlock, *NOAA Deputy Assistant Administrator for Science*, described the work of the Office of Atmospheric Research (OAR) in its partnership with the National Weather Service, as not itself developing forecasts, but of improving model and forecasting tools to enable better weather forecasting. He emphasized the *strength of partnership* required of both OAR and NWS, to enable OAR to effectively contribute to the range of models, observations, forecasting, and other capability or applications that NWS and other users may consistently and successfully utilize. (He also provided a policy overview in a later session).

Anthony Busalacchi, *president of the University Corporation for Atmospheric Research (UCAR)*, encouraged a more unified approach to the modeling system and identification of the impediments to progress in translating research to operations. He noted that R2O translates science for the betterment of society and urged that we cannot stay in a *business-as-usual* state of mind. He recommended making this workshop be different in its outcomes by focusing on what is needed to make R2O a success; to hold NOAA and other leadership accountable to implement the goals of the Joint Technology Transfer Initiative (JTTI), affirming that progress depends upon implementing the recommendations emerging from this workshop.

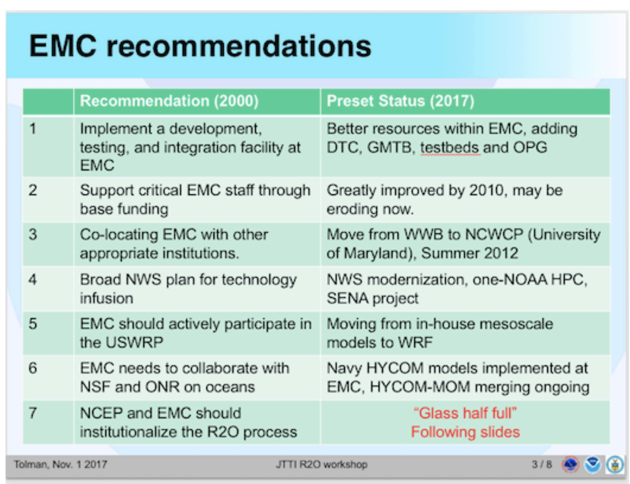
Mary Erickson, *Deputy Assistant Administrator of the National Weather Service*, provided background on research and development transitions in the NWS, citing the value of community engagement mechanisms for NWS/NCEP such as the UCAR Community Advisory Committee for NCEP (UCACN), and its Model Advisory Committee (UMAC). UMAC's review of the NCEP Prediction Suite, in 2015, offered strong recommendations for a unified, collaborative modeling system and strategy across NOAA; development of a comprehensive strategic plan; and better leveraging of the external community, academic and private sectors, and Cooperative Institutes. She encouraged *early-in-the-process* consideration of R2O: that when outlining proposals/projects, begin with thinking of the potential for operations that the proposed research may hold—having an idea on advancing operational model investment from the beginning can accelerate the R2O process. Give consideration to all implications of how best to utilize funding that improves the processes for R2O. She recommended working within the guidelines of the Weather Act (2017) and utilizing the strengths of NOAA Cooperative Science Centers (CSCs).

Gary Matlock, *NOAA Deputy Assistant Administrator for Science,* provided a more detailed *overview of NOAA transitions* that included history of NOAA *policy development and fundamental concepts* supporting O2R2O from roughly 2000 to the present. Key points include:

- *Fundamental nature of O2R to NOAA* – NOAA is focused on identifying process obstacles, and the ways to overcome those, to anticipate new obstacles to R2O and to ably track both research and transition activity.
- The *logic model* for O2R2O transition consists of *inputs (*prior research, previous models, observations, NOAA policies, transition plans, strategic plans) leading to *—> activities* (radar research; storm research, model development) leading to *—> outputs* (model improvement, publications, transition to operations) leading to *—> outcomes* (better forecasts; saved lives; protected property). This logic model makes it clear that O2R—operations requirements and inputs to research—precedes R2O, research to operations.
- Matlock's emphasis was to *start with the outcomes wished for*, and *identify the linkages back* to the outputs, activities, and inputs, so one gains a comprehensive picture for a targeted process. How to quantify this process has been a challenge, and historically, not as successful as it could be.
- *No transitions, no outcomes*: successful O2R2O requires partnership and *early joint planning,* includes a *push-pull* dynamic between research and operations, and that the parties in the entire cycle must be *jointly engaged, committed, and owned.*
- Current transition measures include requirements for transition plans and adoption of a hierarchy of research to development *Readiness Levels* (RLs)*.* Emphasis is on building and expanding a culture of transition at NOAA, tracking of research and development and R2O2R, or R2X (*X* being all-inclusive for operations/applications/commercial product development). "What gets measured gets done; what gets tracked gets done."
- *Summary*: R2X requires *early planning, early partnerships, institutional process, supporting culture, and resources*.

Discussion included acknowledgement that the OAR/NWS partnership to support transition was initially somewhat difficult but has evolved so that both organizations are engaged and collaborating in jointly devising Requests for Proposals, and proposal review. Another participant noted that the gap between outputs and outcomes is a likely locus for social science engagement in operational R20 planning. Cortinas summarized the discussion by noting that the focus of this meeting is on how to continue to improve and effectively cross what at one time was an R2O transition chasm.

Hendrik Tolman, *Office of Science and Technology Integration*, summarized a *review of progress in NOAA transitions*, beginning from the National Academy of Sciences report published in 2000: *From Research to Operations in Weather Satellites and Numerical Weather Prediction (NWP) – Crossing the Valley of Death*. The report discussed steps to explore issues around the transition from research and development to operations, specifically within the area of weather prediction utilizing *two separate case studies*. These were: 1) NCEP NWP model development, and 2) the transition of satellite sensors developed by NASA and used in the National Polar-orbiting Operating Environmental Satellite System (NPOESS) program into operational capabilities on NOAA operational weather satellites. The execution of these two case studies as early transition examples resulted in Environmental Modeling Center (EMC) recommendations in 2000 that were generally accomplished by 2017, though some programs were discontinued (NPOESS) and others merged, and a few recommendations had mixed outcomes. The "do it alone" approach of these two separate case studies illustrates the shift and growth in policy and practice that have evolved over time, with focused effort and attention.



	Recommendation (2000)	Preset Status (2017)
1	Implement a development, testing, and integration facility at EMC	Better resources within EMC, adding DTC, GMTB, testbeds and OPG
2	Support critical EMC staff through base funding	Greatly improved by 2010, may be eroding now.
3	Co-locating EMC with other appropriate institutions.	Move from WWB to NCWCP (University of Maryland), Summer 2012
4	Broad NWS plan for technology infusion	NWS modernization, one-NOAA HPC, SENA project
5	EMC should actively participate in the USWRP	Moving from in-house mesoscale models to WRF
6	EMC needs to collaborate with NSF and ONR on oceans	Navy HYCOM models implemented at EMC, HYCOM-MOM merging ongoing
7	NCEP and EMC should institutionalize the R2O process	"Glass half full" Following slides

Key elements for efficient R20:

- *O2R before R2O* can enable mostly incremental upgrades, or occasional revolutions. Revolutions are far more expensive, but *technology advances* enable revolution, especially when combined with modern code management and hard reinforcement of best practices.
- *Governance* has changed: operations, federal research, and academia can collaborate as integrated teams, planning development in multi-year timeframes, with code management that supports research and development.
- These changes can enable an end-to-end process available to all, with input, verification, and validation tools, and test protocols.

- What makes the difference is to use a framework for transition that incorporates operational considerations from the beginning.

Derek Parks, *Technology Transfer Program Manager, NOAA Technology Partnerships Office,* presented an *overview of intellectual property (IP) and software transitions*, in R2O. Parks noted that NOAA is using more and more community and collaborative development to meet its mission but cautions that hidden IP issues can be a significant barrier to a good transition plan, and open source licenses can impact use and adoption of new technology. Three categories of *IP and ownership* include:

- *Federal employee-developed:* government may patent and license a technology; written works (i.e. software) are Public Domain—there are *no* domestic ownership (copyright) or licensing rights.
- *Grantee-developed:* these products are governed by the Bayh-Dole Act; the *university* has first right to patent; it may also copyright students' software and license to others; the government has a paid-up license to use or have a product used, for 'government' purposes.
- *Contractor-developed:* products are subject to the IP rights in the applicable contract.

License scenarios include:

- *Open Source License:* allows use/modification at no cost, with restrictions; various license types exist; when multiple licenses are applicable, the most restrictive license must be used; is *not the same* as Public Domain.
- *Exclusive/Non-Exclusive Licenses:* enabled by an ownership right (patent, copyright); allows use, usually in exchange for considerations (financial or other); may be revoked by licensor; has legal teeth.

Key Considerations:

- *Transition to operations*: have we resolved all ownership questions before we transition co-developed products into NOAA operations?
- *Public good vs. Licensing*: what are the limits of the Government Use license? How do we balance income, collaboration, and mission requirements?
- *Derivative works:* How can we ensure derivative works properly credit both NOAA and collaborators?
- *Think about these issues early, and often.*

Christopher Hedge, *NOAA/NWS Federal Program Officer*, provided an *overview of funding opportunities* available via the Office of Science and Technology Integration (STI). STI supports collaborative research through four main programs:

- NGGPS: Next Generation Global Prediction System
- S2S: Seasonal to Sub-seasonal (Weeks 3-4) forecasting improvements
- HFIP: Hurricane Forecast Improvement Project
- CSTAR: Collaborative Science, Technology, and Applied Research

His presentation detailed early February 2018 companion Federal Funding Opportunities (FFOs) in these program areas. Priorities include collaborative projects with the *Environmental Modeling Center (EMC)* or *National Hurricane Center (NHC)* researchers, including subseasonal to seasonal (S2S) research projects; data assimilation, prediction, ensemble development, post-processing, verification; advances in the prediction sub-system; ensemble development; and post-processing techniques. Also available are collaborative opportunities with NOAA Testbeds modeling projects and needs of NWS regions and field offices to improve overall forecasting and warning capabilities through collaborative research. *More detail on these opportunities is available in the Hedge Powerpoint presentation, including contact information.*

John Cortinas, *OAR OWAQ Director*, provided an overview of *funding opportunities for transition from OWAQ* supporting improved high-impact weather products and services through research in *modeling, observations, and decision support*. The two primary mechanisms are 1) *US Weather Research Program TestBed Funding*, and 2) the *Joint Technology Transfer Initiative (JTTI)*. For Testbed funding, there are three separate opportunities available every two years (~$2M). Proposed two-year projects are for the Hazardous Weather Testbed, Hydrometeorology Testbed, and Joint Hurricane Testbed. JTTI emphasis is on moving *applied research projects* through a transition process. Opportunities that support transition of research to improve operations typically cover Readiness Levels 4-8; priority areas are determined by OAR and NWS. Projects benefit the general weather enterprise, especially NWS operations; they must include rigorous testing, evaluation, and management plans. In summary, OAR and NWS plan and execute programs jointly, coordinating their request for proposal (RFP) calls. OAR/OWAQ supports competitively selected projects that focus on development and demonstration of models, observations, and techniques that could improve NWS products and services; and moving applied research projects through the transition process. NWS calls will focus on the higher readiness levels (e.g. modeling), while OAR will focus on the mid-level RLs, seeking development in terms of operations.

Discussion: A question about the level of community response to RFPs was put forth; Cortinas noted that the response on OAR opportunities thus far has not been as high as wished; OAR welcomes all inquiries. He affirmed that inclusion of social science aspects is implicit in OAR funding opportunities. Good RFP response has been received on the NWS HFIP RFP; testbeds are much more product-focused, whereas decision-support foci include more social science aspects. The Climate Program Office has worked to improve seasonal to subseasonal offerings, and would welcome a joint effort with NWS on S2S calls.

Session 2 – Promises and Challenges of R2O

Contributors:

- *Joe Pica – Director, NWS Office of Observations*
- *Hendrik Tolman – Office of Science and Technology Integration*
- *Gina Eosco – Social Scientist, Cherokee Nation Company supporting NOAA/OAR/OWAQ*
- *Steve Ackerman – Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin*
- *Robert Fovell – University of Albany, State University of New York*
- *Ed Clark – Director, National Water Center, NOAA Office of Water Prediction*
- *Jerad Bales, Executive Director, Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI)*

- *Jennifer Mahoney – NOAA Earth System Research Laboratory (ESRL), Global Systems Division (GSD)*
- *Reza Khanbilvardi – NOAA Cooperative Remote Sensing and Technology Center (CREST), City University of New York (CUNY)*
- *Arun Chawla – Chief, Coupling & Dynamics Group, Modeling and Data Assimilation Branch, Environmental Modeling Center (EMC)*
- *Dan Barrie – Modeling, Analysis, Predictions and Projections (MAPP) program, Climate Program Office (CPO), OAR*

Joe Pica - *Director of the NWS Office of Observations* gave a detailed summary of *observations and instrumentation for NWS operations.* Pica reiterated the tenets of the Weather Ready Nation (WRN) effort: to build community resiliency in the face of increasing vulnerability to extreme weather, water, and climate events, encompassing the entire US weather, water, and climate enterprise, and to provide impact-based decision-support services (IDSS).

The *NWS Observations Portfolio* is responsible for the collection of space, atmosphere, water, and climate observational data owned or leveraged by the NWS, across the entire global observing system. Pica highlighted the coordination and collaboration that occur across the agency via internal councils (NOAA Observing Systems Council, especially) as well as inter-agency and international collaborative efforts. He noted the recent investments in observing infrastructure that are ongoing in NOAA to launch new satellites (GOES-15, etc.) and revitalize surface observing systems to extend their useful life (e.g., NEXRAD). He mentioned technological improvements and efforts to leverage data buys in the observing portfolio.

Challenges include: 1) optimizing the observing portfolio more rapidly by incorporating new technologies—seeking to improve by conducting the Emerging Technology workshops effort in 2016 (July) and 2017 (August); and 2) leveraging observations more intelligently to ensure that tight budgets are best utilized to optimize the observing portfolio. One anticipated scenario is that base observations would hold steady while the most significant observation expansion would be by increasing use of leveraged data in the future. To address this potential scenario, NOAA will need to be able to determine the best mix of fixed and mobile platforms, including autonomous vehicles; to utilize emerging crowd-sourced information; to employ miniaturization and commoditization of sensors; to employ efficient and novel uses of communications techniques; and to better define the respective expected roles and ownership of government and private sector observations.

Discussion included a request for clarification on what is meant by *leveraging*: making efficient use of services where possible from multiple sources: research, academia, non-profits, commercial developers, foreign sources—anything not under NWS control that NWS might be able to leverage to benefit services and capacities. The importance of coupling of ocean observations with atmospheric observations was acknowledged. Others noted that problems can arise with commercial data provision, especially with respect to research: if paid for, then availability to the research community can become problematic due to data rights issues. The presentation included additional detailed information on observational infrastructure in satellites, and planned investments for improvements in observational infrastructure.

Hendrik Tolman, *NWS Office of Science and Technology Integration*, provided a detailed overview of the current status and future evolution of the NCEP Production Suite for a *unified modeling and data assimilation* suite, and a *unified forecast system*. The Production Suite is emerging from multiple efforts, and from vision to roadmap, to strategic implementation plan.

The *vision* focused on products supporting *unified modeling and data assimilation* (coupled, ensemble-based, re-forecast and re-analysis including pre- and post-processing, calibration, verification, validation); community modeling; evidence-driven decision-making; with transparent and robust governance. The *roadmap* outlined moving from a patchwork quilt of models and products—the result of implementing solutions rather than addressing requirements—to a product-based *unified forecast system* that covers present elements in a more systematic and efficient way. The *Strategic Implementation Plan* (SIP) 1.0 is forthcoming by the end of the CY17; it will be a three-year single integrated plan for FY 2018-2010 coordinating activities of NOAA and external partners to build a unified modeling system, with NGGPS as a foundation. It will be accompanied by an associated Governance document and a Communications and Outreach Plan.

The SIP vision anticipates engaging community in multiple layers with varying roles:

- *Researchers, users, and stakeholders:* conduct research and testing on publicly available models; provide long-term science contribution; source of next-gen STEM workforce;
- *Trusted super users*: selected R&D users that can test/evaluate prototype models prior to baselining and public release;
- *Core development partners*: organizations that are actively involved in development of next-gen operational unified modeling system including NOAA operations, R&D and program offices, NCAR, NASA/GMAO, Navy/NRL, and JCSDA;
- *Operations*: centers that own/operate operational versions of the unified modeling system;
- These community elements *constitute the NCEP Production Suite.*

Gina Eosco, *Social Scientist supporting NOAA OAR/OWAQ,* presented on *Social Science R2O: Challenges, Success, and Our Future.* She ably explained how *early-on social science integration* with operations and between operations and research communities can clarify misunderstandings; improve communications internally and externally; ensure inclusivity; expand understanding of processes, process change, and iteration. Communication between operational communities and social science research communities is essential to mutual understanding, and mutual gain. Working groups that bridge roles foster worthwhile understandings that translate into effective communication and better overall service to and from providers and end users of NOAA products and services. These improvements in turn meet Weather Ready Nation goals for improved forecast communication and effective communication to decision-makers, and significantly facilitate the integration of research community contributions into operational environments.

Steve Ackerman, *Cooperative Institute for Meteorological Satellite Studies; University of Wisconsin* gave a presentation on *R20 in Satellite Observations*. CIMSS is a NESDIS Cooperative

Institute (CI). CIs are collocations of NOAA and university scientists forming a community immersed in a collaborative environment. NOAA supports 16 Cooperative Institutes consisting of 42 universities and research institutions across 23 states and the District of Columbia.

Ackerman characterized the traditional research-to-operations metaphor (crossing a bridge to overcome the "Valley of Death" to successfully integrate) as being too simple. There are multiple bridges, and no one bridge will work in a particular crossing. Instead he offered a conceptualization of R2O as being more dynamic than a bridge—not an isolated process for single deliverables, but a *holistic process*, as the R2O cycle delivers research results that fit into operations. He likened Cooperative Institute operations/research collocation environments to being like a slinky – they move and change, are dynamic and more flexible.

He illustrated the successes of CIs via examples from CIMSS/NOAA collaborations: providing NOAA with rich, stable, and flexible research environments to help fulfill their mission. Collaborations have involved basic research; accomplished experimental product development; and participated in the transition of research products to operations. His emphasis was that NOAA investment that has focused on monolithic ground systems development and delivery has had the effect of limiting the ability for dynamic user-inspired science-driven products or processing. Utilizing universities as frameworks for collaboration and ideal places for demonstrating new or evolved products and applications can contribute to *making a better bridge/slinky*.

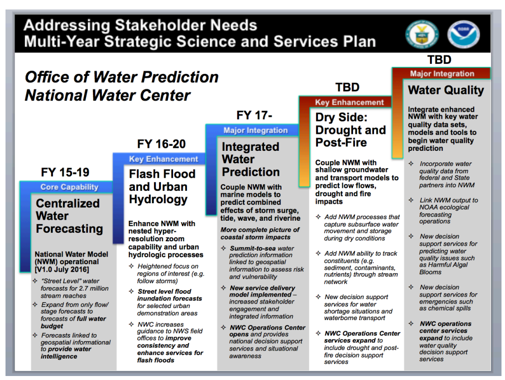
Summary: CIs are research communities that include NOAA and University scientists; the core to the successful relationship, and key success in transitioning research to operations is *collaboration*. The successful R2O culture requires the operations side to invest in new research and development that will ultimately support their mission. The research side is open to understanding why operations makes certain requests, and how operations is leveraging research outputs.

Robert Fovell, University of Albany, State University of New York gave a detailed presentation on *Contributions to the HWRF modeling system* that illustrated successful collaboration between the research and operational communities in Hurricane Weather Research and Forecasting (HWRF) projects, including *Cloud-radiative forcing (CRF) in HWRF* (demonstrating how and why CRF influences storm size); *Planetary boundary layer (PBL) mixing in HWRF*; and *PBL depth in HWRF***.** These R2O projects were accomplished in collaboration with the Hurricane Forecast Improvement Program (HFIP) and the Developmental Testbed Center (DTC). He noted that DTC resources were crucial to their HWRF work, and included documentation, code support, scientific expertise, retrospective experiments and tests, training, test data sets, and visitor support. Fovel noted that there can be a very beneficial dynamic operating between practical/operational focus vs. curiosity-driven research: with the advantage of new/different eyes, the research team went from never having worked with HWRF to finding a serious flaw within one week. The current HWRF model is using a fix that his team contributed. The presentation offers significant detail on the research described, with citations.

Ed Clark, Director, National Water Center (NWC), gave a presentation on the *National Water Model (NWM): Research to Operations.* He described the partners and services involved in the NWC-generating Integrated Water Resources Science and Services (IWRSS) collaboration, including NOAA, USGS, US Army Corps of Engineers, and FEMA (original collaborators). Since that time, the partnership is expanding to include CUAHSI (see below), NCAR, NASA, NSF, U.S. Depts. of Agriculture (USDA), Energy (DOE), and Interior (DOI), and U.S. Forest Service.

Clark gave background information on the National Water Center and the National Water Model it employs operationally. Its development was generated in response to rapidly growing needs for improved water stakeholder information; for integrated understanding of near- and long-term outlooks and risks; for consistent, high resolution analyses, predictions, and data to address critical unmet information and service gaps; and the need to transform information into *actionable intelligence* by linking hydrologic, infrastructural, economic, demographic, environmental, and political data.

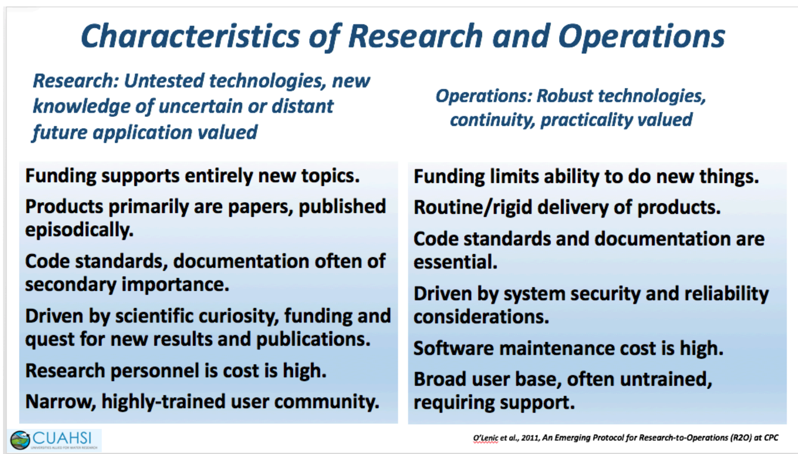
The Center is multi-purpose: it serves as a center for excellence for water resources science and prediction; as a catalyst for enterprise collaboration; and as an Operations Center with a common operating view and decision support services surrounding water resources. Operationally it employs the National Water Model (NWM), the core of which is NCAR's Weather Research Forecasting Hydrologic Model (WRF-Hydro), providing a continental scale modeling approach producing consistent "neighborhood level" information to address stakeholder needs, with the goal of producing spatially-continuous forecasts of soil moisture, evapotranspiration, runoff, snow water equivalent, and other parameters. The progression of implementations and advances to use of the model are shown below.



Clark's presentation also detailed future science and technology challenges/limits to improving water prediction capability and related services, and gave examples of highly successful recent support provided by the NWC in severe weather events, including a rainflow/streamflow animation generated by the model for Hurricane Harvey several days in advance of the event, and experimental flood inundation maps based on the NWM analysis and 5-day forecast for Hurricane Harvey. These maps supported emergency management efforts to stage supplies in non-flooded areas and to target relief efforts. NWC is a highly collaborative endeavor, a cross-NOAA, interagency, and academic partnership. *Renewed and sustained engagement with the* *research community is critical and essential to rapidly evolve the model and the water prediction system and services.*

Jerad Bales, *Executive Director* of the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) followed Ed Clark in detailing CUAHSI's *R2O experience on the National Water Model: Research Community Perspective.* CUAHSI is a 501(c)3 non-profit consortium of about 130 U.S. academic institutions, non-profits, and international universities. Its mission is to shape the future of water science by strengthening collaboration; developing and delivering data, models, instrumentation and technologies; and promoting education.

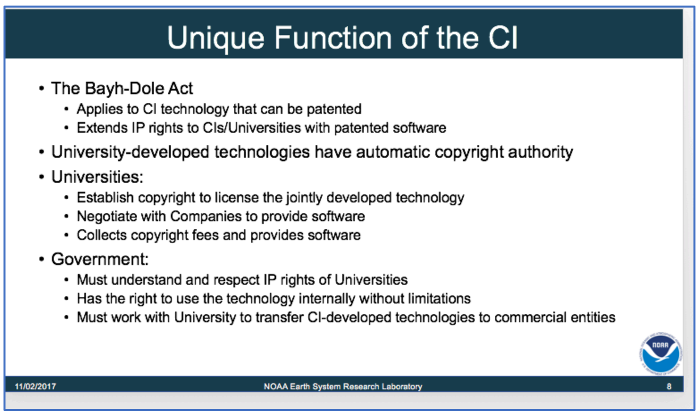
His presentation included a comparison/contrast between research and operations. He noted that the mission to meet operational requirements and the opportunities to improve and expand predictive capability and services create a dynamic tension that is inherent in decisions about how and to what extent research and technologies can be transitioned into an operational service system.



CUAHSI and the National Weather Service also conduct Summer Institutes for a six-week, on-site residential program for 30-40 graduate students engaged in project-based teams of 3-4 graduate students each, utilizing the National Water Model in some way. The program has trained more than 100 graduate students on the NWM, creating next generation researchers, users, and operational workforce. CUAHSI's continuing role is to work with NCAR on governance; provide community tools through HydroShare (open source collaborative environment for data and model sharing), including documentation and version control of apps and tools; provide community data sets for selected use cases through CUAHSI Water Data Services; continue the Summer Institute; and organize and host NWM Community Users Meetings.

Jennifer Mahoney, *NOAA Earth System Research Laboratory (ESRL), Global Systems Division (GSD),* gave a presentation exploring the *Roles of NOAA Labs and Cooperative Institutes in NOAA transitions in R20.* GSD's focus is on improving weather data, forecasts, and computing techniques used by industry, decision-makers, and stakeholders to make operations safer and more efficient. GSD is the developer of the High Resolution Rapid Refresh (HRRR) real-time, hourly-updated, cloud-resolving, convection-allowing atmospheric model.

Laboratory and Cooperative Institute (CI) partnerships enable the development and transition of technologies: CI staff work in a NOAA lab to achieve NOAA mission goals, and NOAA staff serve as science advisors to CI staff. CIs include CIRA: Cooperative Institute for Research in the Atmosphere, at Colorado State University in Ft. Collins, Colorado, and CIRES: Cooperative Institute for Research in Environmental Sciences, at the University of Colorado – Boulder. R2O and R2X are governed by cooperative research and development agreements (CRADAs) between government laboratories and private companies or universities for research and development. Her presentation detailed the requirements and functions of CRADAs and the interactions among all parties.



A transition is not successful until it is fully installed and running in an operational environment, therefore *successful hand-off is critical*. Successful transitions require strong partnership between operations and labs; good software development practices; strong and constant communication; constant testing; and development of a Joint Research to Operations Plan (schedule, operational platform, clear expectations).

Reza Khanbilvardi, *NOAA Cooperative Remote Sensing and Technology Center (CREST) at City University of New York (CUNY),* spoke on the topic of NOAA R20 through *Cooperative Science Centers (CSCs).* There are four primary NOAA CREST centers:

- Florida A&M University – NOAA Center for Coastal and Marine Ecosystems (CCME)
- Howard University – NOAA Center for Atmospheric Sciences and Meteorology (NCAS)
- City College of CUNY – NOAA Center for Earth System Sciences and Remote Sensing Technologies (CESSRS)
- University of Maryland Eastern Shore – NOAA Living Marine Resources Cooperative Science Center (LMRSCS)

These institutions partner with about 25 additional universities across the nation to meet NOAA research and education goals. Key points he noted with respect to the transition of research to operations activities were: 1) NOAA Technical Readiness Levels: most scientists at universities *do not know where their work stands* within the Readiness Level structure. More understanding and communication is needed; 2) when speaking about the transition of research to operations (R2O), we are usually talking about *NOAA-conducted research and development* to NOAA operations. Khanbilvardi summarized successful transitions that have taken place, or are about to, from CREST-supported work, including:

- River and lake ice mapping product using NPP/JPSSVIIrS sensor;
- Harmful algal bloom (HAB) detection techniques (*Kerenia brevis* blooms) from satellite imagery;
- IDEA: Infusing Satellite Data into Environmental Air Quality Applications;
- CREST LIDAR Network (NY, VA, MD, PR): vertical profiling along the Atlantic coast from New York to the Caribbean, with applications to aerosol transport and air quality;
- Urban Weather Research Forecast model: uWRF – coupling of NCAR-WRF to urban parameterization schemes;
- CREST R&D products – ISCCP Cloud products, through leveraged support from university grants and other agency funding.

Challenges in R2O transition, from an academic research point of view, include:

- When an excellent theory innovation is made, it is critical for a NOAA team or individuals to recognize its importance—this can be a primary roadblock: convincing NOAA of an innovation because most innovations presented to NOAA do not, at least initially, *appear* to have operational value.
- Barriers to risk-taking: there are inherent constraints on NOAA agility that may be perceived as inflexibility.
- Funding that is inadequate, irregular, or unreliable.
- Transition process backlogs – delays that have difficult impacts on university research efforts.
- Priority setting of the entire 02R2O process by the agency.
- Not sufficient coordination with other agencies.

Suggestions to make things easier:

- Clearly define the goals of proposed R2O activities.
- CSCs could create innovation teams to effectively market research innovations, help to overcome barriers.
- Provide resources: budgets, expertise, Testbeds, to CSCs.

Discussion followed on the relevant NOAA unit and the nature of the interactions. Khanbilvardi noted that within the CSC/NOAA environment, the interactions are generally good when there is a match between CSC interest and NOAA science interests. This may not happen until something is at the point of maturity, where benefit begins to be recognized. Typically, starting engagement has come from CSC scientists. He noted that for the majority of 15 years, his work has been with NESDIS, however, in the last five, he has worked frequently through OAR, which opens new opportunity for their CSC.

Arun Chawla, Chief, Coupling & Dynamics Group, Modeling & Data Assimilation Branch, Environmental Modeling Center (EMC), presented a case study as an *R2O development paradigm*: WAVEWATCHIII and the National Oceanographic Partnership Program (NOPP). Wavewatch III is a deep-water wave model (structural development by Hendrik Tolman v.2.22; 2002). In 2010 there was an initiative to bring about recent advances in modeling, and EMC took the opportunity to make Wavewatch 3 a *community code*, resulting in a significant upgrade and public release. EMC strongly supports community modeling, and set up best practices to support transition to operations. The Wavewatch model is now a *community development paradigm*, with code ownership distributed over multiple groups in different countries, and with version control in place to manage different contributions.
Benefits of the collaboration include 1) emergence of a new physics package, developed offsite from EMC, on a common repository, achieved in nine months; and 2) Wave Hurricane coupling which emerged from a student development project; this was put in the common code base, was operational in three months, and is now part of ongoing operations.

Summary: What is needed for successful transition:

- Common code base for development with strict rules that are enforced;
- Clear two-way communication between EMC and researchers;
- Development tested in conditions pertaining to operational needs (as far as possible);
- A smoothly functioning R2O pathway significantly reduces the time it takes to bring research ideas into operations, and for researcher/developers to see their work being implemented in operations.

Discussion centered on curiosity about working in a common code base: common code is kept out of operations, in a trunk version, with strong version control. Everyone is expected to immediately update their version. This was a good example of the social science issue noted earlier about the difficulties of doing things differently; it took some adjustment. We need continuing discussion on how best to accomplish enforcing of common repository use.

Dan Barrie, Modeling, Analysis, Predictions and Projections program, Climate Program Office, OAR, gave a presentation on *Research Transition Activities* within the Climate Program Office. CPO is a competitive research program in OAR focusing on a broad research mission ranging from observations to models to societal impacts for climate. CPO supports *applied R&D*; funded projects range from fundamental applications to operational transitions. The focus is on enabling the external community to work with NOAA labs and centers. Examples include R20 from CPO programs and the R2O process used by the Climate Test Bed. CPO divisions include:

- *Atmospheric Chemistry, Carbon Cycle, and Climate (AC4)* program – nitrogen cycle, atmospheric composition from space; Carbontracker; urban emissions, emissions and chemistry of wildfires; oil and gas emissions; field campaigns, process and earth system modeling; sustained observations.
- *Climate Variability and Predictability (CVP) program* – advance knowledge of dynamics, sources of predictability, of coupled ocean-atmosphere-land-ice system across all climate time scales by using observations, modeling, research, analysis, and field studies

to gain process-level understanding of how the system interacts.

- *MAPP – Modeling, Analysis, Predictions, and Projections* (MAPP) – centered in subseasonal to seasonal work: prediction from weeks to decades; climate analysis re-analysis and data assimilation; climate and Earth System modeling; drought and other applications; climate projections—five core research areas mainly via 3-5 year competitive grants. In S2S time scale: there is *no natural boundary between "weather" and "climate*"; key climate features such as El Nino make extended range prediction feasible. Testing prediction tools via Climate Test Bed - 14 current MAPP-CTB projects will test experimental subseasonal prediction systems.
- The *Climate Test Bed* is a joint partnership between NWS/NCEP and CPO/MAPP. The focus is on *transitioning research-derived modeling and forecasting capabilities and products into operations.* New capabilities resulting include: *North American Multi-Model Ensemble* (NMME), drought capabilities, new forecast products including subseasonal outlooks, advances in operational tropical cyclone forecasting. NMME success was based on clear operational requirements, a cooperation agreement, research and operational value, clear research and operational protocols, availability of output, and responsiveness to research needs.

Summary: CPO supports research across Readiness Levels, using a rigorous competitive process; many CPO activities are relevant to the Weather Act supporting Weather Ready Nation. The Climate Test Bed (CTB) provides mechanisms for transition-ready research, using a rigorous transition planning process since 2014.

Session 3 – Support for O2R

Mechanisms supporting operational systems to the research community.

Contributors:

- *Bill Kuo, Director, NOAA Developmental Testbed Center (DTC); Director, UCAR Community Programs*
- *Tom Auligne – Director, Joint Center for Satellite Data Assimilation (JCSDA)*

Bill Kuo, Director of the Developmental Testbed Center (DTC), and Director of UCAR Community Programs (UCP) gave an overview and summary of DTC mission and activities, facilitating *interaction and transition of numerical weather prediction (NWP) technology between research and operations.* DTC is jointly sponsored by NOAA, the Air Force, NSF, and NCAR as a framework for bringing together operational capabilities and research innovations. *O2R* activities include support for current operational NWP systems to the community*; R2O activity* is in performing testing and evaluation on promising NWP innovations for operational implementation.

DTC's *Software system philosophy* is to provide a framework bringing together operational capabilities and research innovations in R2O, which includes ongoing distributed software development for current operational systems, and testing and evaluation on NWP innovations for possible operational implementation. Periodic releases are made available to the community that include latest capabilities and techniques. Centralized support is provided by DTC, for software downloads, documentation, tutorials (online and onsite), and provision of an email helpdesk. This ensures PI knowledge of coding rules and standards; and training on code implementation and management. Recent areas of development and accomplishments include:

- *Software containers in NWP* – containers allow software systems and everything required to run them to be bundled in isolated containers, ready for development, shipment, and deployment. They are highly portable; can be used in cloud computing; are sharable and replicable. They reduce spin-up time for setting up software systems and provide greater efficiency in producing model output. Docker, a leading software packaging provider, is used to package applications inside a software container. *Common Community Physics Package (CCPP)* – a collection of *dycore-agnostic physical parameterizations* – can be applied to different dynamical cores (dycores). Software can contain multiple schemes for each type (PBL, cumulus, etc.) to support various applications and maturity level (operational, developmental).
- *Physics Testbed* – a new development related to the CCPP supporting open community participation at various levels of development: sandboxes (never commit); open community/commit when collaborating; core partners (review committee) provide control and maintenance of operational physics suites.
- *DTC support for O2R2O* – community support for WRF, HWRF, UPP, GSI/EnKF, and MET; developer support for HWRF (repository access, special training); datasets for cases important to operations; Global Model Test Bed support is under development (physics package); visitor program (year-round call), and community workshops and outreach.

Lessons learned from O2R20:

- Effective O2R community and developer support is critical to engage the academic community in R2O;
- O2R2O needs to be a fully integrated process to be effective: requires an integrated team including PI, DTC, and EMC, with each properly resourced;
- Project coordination from the very beginning (not a 'throw over the fence' approach).

Discussion included a question about the private sector with respect to DTC-facilitated and supported involvement. There is no restriction to private sector involvement, except with respect to the promise of ensuring a *community systems* approach.

Tom Auligne*, Director, Joint Center for Satellite Data Assimilation.* Auligne drew distinctions between what money can and cannot do, as taken from JCSDA experience in accelerating and improving quantitative use of research operational satellite data. Resources can bring about proposals (JCSDA external research); supercomputers (hardware, basic software, and IT); scientific software Integration (the hardest part here is keeping in sync with operational models); resources to sustain portability, documentation, and user support; utilities to help scientists (CRTM, assessment, formatting tools); and rigorous software configuration systems and testing mechanisms.

What money cannot buy is the right culture, fostering of which requires *transparency of R2O protocols and willingness* to accept research performed by researchers and to work collaboratively (on the part of the operational partner); and willingness to work/start with an operational system, follow protocols and accept constructive feedback (on the part of the research partner). It is important to understand and accept that R2O is not for everyone: *careful choice of research and operations partners* is critical.

Auligne presented common scenarios illustrating technical difficulties as well as cultural challenges:

- New satellite instrument development: observation processing will be *developed several times.*
- Algorithm: a new development may be tested with a (semi-) toy model, resulting in a publication with '*encouraging results'*. The end. *Few algorithms get evaluated in operationally relevant environments*.
- Technology transfer: importing science from external collaborators can mean reading their publications and *recoding from scratch*.
- *Bad design is bad for R2O*. Operational code development has typically been decades in development and for a specific application usually. This is bad design hurting R2O. Thinking through development from start to end and having engagement between both communities from start to end is critical.
- *Modern software engineering* – we want very flexible, reliable, efficient, generic, readable and modular code. This is not specific to NWP—the software industry moved to generic and object-oriented programming 20 years ago. The key idea is *separation of concerns:* all aspects exist but scientists focus on one aspect at a time; different concepts should be treated in different parts of the code; no one can know it all. *Code efficiency and portability* is important: experience shows that refactoring generally improves code performance; new structure will make scalability investigations easier.

He followed with examples of current collaborative activity and benefits, centered on *JEDI* – the *Joint Effort for Data assimilation Integration*, a collaborative development spearheaded by JCSDA partners creating next-generation unified data assimilation, applicable to research and operations, and designed for mutual benefit as much as possible without imposing a single approach. The vision of benefit is to facilitate *innovation* to address scientific challenges; *increase R2O transition rate*, and increase *science productivity and code performance.*

- The *JEDI Unified Forward Operator* (UFO) – the UFO introduces standard interfaces between the model and observation worlds; observation operators become *model-agnostic* making sharing, exchange, and collaboration more available. The objective of UFO is to build an "Op Store" platform for the community.
- *JEDI Ecosystem* bridging R & O – modular, flexible, code portability that *pays the technical debt:* writing clean code at higher cost and delayed delivery vs. writing messy code cheap and fast at the cost of higher maintenance efforts once shipped.

In summary**,** 02R and R2O are sides of the same coin. Continuous integration is necessary; R2O is a relay-race across the bridge to operations. Success requires right resources, right people, right culture, right software, right computers, and right development ecosystem.

Session 4 – Set-up of Break-out/working groups

The closing session of Day 1 was a brief discussion centered on the logistics of the following day's working group activities.

Day 2: Break-out Groups – Outcomes and Recommendations

Session 5: Break-out Groups reporting

The morning of Day 2 was spent by break-out groups exploring four questions resulting in observations and recommendations in an afternoon reporting session, via presentations.

Questions

1. From your or your organization point of view, what area of weather has *matured research that has not transitioned* to NWS operations? (For example, new observational techniques, numerical modeling techniques, data assimilation techniques, etc.) Can you list two or three *R2O priorities* that you think NOAA should focus on in the next five years?
2. What are some of the *biggest gaps in current weather forecasting* (modeling) that NOAA needs to focus on transitioning in order to fill these gaps in the next five to ten years?
3. From the perspective of your organization, what is the *biggest challenge* your organization faces in transitioning research to operations, other than the funding issue?
4. *Test beds* play a crucial role in transitioning research to operations. Do you know anything about the NOAA test beds? Are the current test beds *serving the intending purpose*? Are they *readily accessible* to the academic and private sector?

Outcomes

NOAA goals for unified modeling approaches, data assimilation, and forecast capabilities on all levels, are generally well-received. But the challenges to achieving those are myriad, given the realities of funding limitations, policy, process, and implementation and timing impediments. Attendees were forthcoming in the identification of the priorities, gaps, and challenges that must be addressed to achieve progress in effective transition of research to operations.

Throughout the small group discussions, the issues that arose most frequently fell into two broad categories: **Technical issues** and **Process issues**, with variable granularity from the particular to the general evident in the responses to all four question topics. A clarification question in one of the groups asked how NOAA defines *matured research*, as that was the basis for the initial question in Break-out group discussion. Jennifer Mahoney, NOAA, defined it as: *research accomplished, but not yet demonstrated in a relevant environment*; generally speaking, at Readiness Levels 5-6, or higher.

A separate umbrella theme of **Social Science issues** threaded throughout all the discussion group responses; that discussion is offered following the Technical and Process issues.

The full detail of the break-out group responses, organized by specific responses received to the four questions presented, is available as *Appendix 3*.

Technical Issues

Primary technical concerns were identified within current practices in *modeling/forecasting*; satellite *data assimilation methods*; *data infrastructure; high-performance computing access*, and *Testbed utilization*.

Modeling

NOAA *global modeling* capability is viewed as not up to standard—especially with respect to use of *four dimensional variational data assimilation*, or 4DVAR; noting that the European Center for Medium Range Forecast (ECMWF) is celebrating 20 years of usage of 4DVAR, and many other countries use it as well. This was identified as a key research-not-transitioned issue.

Leveraging of *community multi-model ensembles* is viewed as a priority and a gap ripe for closure. The High Resolution Rapid Refresh (HRRR) hybrid ensemble is not yet operational, though apparently in Testbed status, and probably at RL6. *Computing resources and proc*essing were identified as barriers to HRRR transitioning. Interpretation of content/products being created was also cited as a gap.

Other research not transitioned includes *urbanized high-resolution climate monitoring*; *hydrological inundation modeling*, complementing that of the National Water Center; and *coastal ocean modeling*. *Improved coupling* techniques of various modeling capabilities are priorities, including atmospheric modeling, ocean modeling and monitoring, coastal modeling and inundation; and incorporation of subseasonal to seasonal (S2S) techniques. In essence, coupling for air-land, land-water, water-air.

The integration of *scale-aware physics parameterizations to unified modeling goals* (within three years) were a strong priority, gap, and challenge across all groups. *Evaluation of the FV3*[1] *model* numerics and boundary conditions is seen as a priority need for supporting a unified model framework.

Repeated calls for advanced *Physics packages implementation* were identified across groups, via a *systematic and controlled approach*. The Common Community Physics Package (CCPP) was suggested as a solution.

Forecasting

Forecasting priority needs not otherwise included in the modeling conversations included implementation of the *Warn-On-Forecast* program, to increase lead time and accuracy of tornado, severe thunderstorm, and flash flood warning (at RL7); and implementation of the next-generation severe weather watch and warning framework: *FACETs* (*Forecasting a Continuum of Environmental Threats*), to enable better public awareness. Additional commentary noted that for *aviation forecast output,* five different verification techniques and

[1] FV3: Finite Volume Cubed-Sphere Dynamical Core: https://www.gfdl.noaa.gov/fv3/

systems (at RL8) have been put on hold; that is, they were on their way to transition, but paused due to funding issues. Tropical Cyclone track, intensity, and structure are also viewed as gaps between ECMWF and NOAA. It was also noted that there is a gap in data requirements to understand sub-grid scale processes; feedback from forecasters into model implementation is needed. Discussion of satellite products included vegetation index, cloud properties, total ozone, low clouds and fog, visibility index, and sea ice concentration. *Algorithms developed for GOES 16 and the Geostationary Lightning Mapper (GLM*) were identified as being "on the bridge" but not operational; the particular discussion group viewed this as a priority.

Data Assimilation (DA) methods

High priorities were identified as *community-developed data assimilation* and *coupling techniques (RL6)*. Breakout group discussions remarked on the twenty years of use of 4DVar methods for data assimilation by the European Centre for Medium-range Weather Forecasts (ECMWF). Other operational centers have implemented advanced DA techniques, and this is viewed as a gap and challenge to more effective numerical weather prediction in the U.S. The need for *high performance computing* resources (HPC) required to support DA was reiterated, as was the need for optimization of systems generally. This issue of not enough HPC access and availability also arose in the Testbeds discussions, framed as causing difficulty in using testbed output.

Data infrastructure

Data generation, storage, and common infrastructure, as well as *reduced access* due to restrictions are all viewed variously as priorities, gaps, or challenges. A comment received about data infrastructure was: "we need to bring users to the data, facilitate a modern big data approach, use server-side computing/thin client model." *Coding infrastructure commonality* for the ease of transition onto operational systems is a priority. The availability of *validation datasets* was identified as a problem: "there is a need to make apples-to-apples comparison with operational systems, but those large datasets are not available." These are restricted vs. non-restricted access problems. *Code repositories*, and "clean rules of engagement" for their use are needed. Recommendations included:

- *Data and resources available at universities* (e.g. observations, high resolution models, ensembles) could be "*certified*" in some way to facilitate leveraging. And data solutions need to specifically target data-sparse regions.
- Data to supply coupled systems needs to be supported.
- Subversion code development and Git/Github training are needed.
- Optimization of systems and computers is needed.

Biggest Challenge Other Than Funding

HPC: *High performance computing (HPC) access* was seen as a quite serious problem and challenge by all groups, and a general view that computing available to research, compared to that available to operations, lags by a very large margin. Specific comments cited include:

- Non-uniform HPC environments across NOAA.
- Achieving allocations or account access to NOAA HPC resources (by academia), ranges from extremely difficult to impossible, jeopardizing altogether useful R2O

collaborations. An example cited was that operational HWRF has branched to code which can only be tested in a NOAA environment. Inability to gain a NOAA account, or the length of time required to do so (one year example cited), prevents such testing. The view expressed was that research computing should be greater than operational computing, but currently, operations HPC maintains priority. Research computing resources need to increase in order to move forward.

- Difficulty in transitions of upgrades, and transition issues between different HPC systems; inability to replicate information streams used in operations, off-site.
- Availability of validation datasets.
- Code optimizations needed for operational performance often break portability for research purposes; causing code divergence.

Other identified gaps include the *general optimization of systems.* Software compilation and dependency issues might best be addressed by using container solutions like Docker. Other topics identified as gaps included *air quality*, *fire weather*, *planetary boundary layer (PBL)* and *soil moisture data*.

Testbeds

While discussion groups observed that testbeds appear to generally meet their purpose, it was also stated that modifications are needed. Testbeds are functional, but their computer resources are limited. They are retrospective; operational use is limited; each use has a specific need, but data is missing in some cases. Testbeds were faulted for not providing adequate feedback in some instances, being too inflexible, and not very responsive. Perceptions about testbeds include:

- Researchers don't know about testbeds and their core goals.
- There are many testbeds; they are wide ranging; it is difficult to deduce common problems and solutions.
- Awareness of the testbed functions is limited to the communities to which a testbed caters. The perception is that testbeds are narrowly focused.
- It doesn't feel like there is an open invitation

Recommendations suggested moving to *cloud-based computing*; *structuring testbeds to support a unified modeling system*; devising a *global model testbed* that covers more than just the atmosphere; the need for an *end-to-end testbed*, mimicking an operational environment, was suggested. Another technical/social issue was identified with respect to reforecast: commit to reforecasting, but *how* it is done is important. Don't make it an impediment, i.e. is it always necessary to do a 30-year reforecast every time a model is updated?

Other suggestions included making use of *R2O liaisons*; visiting scientist and postdoctoral visitors to testbeds; making use of the National Weather Association (NWS) professional society for operational meteorology as a *catalyst for change*; better connections with Weather Forecast Offices (WFO) and Science and Operations Officers (SOOs). *Create incentives* or milestones for operations to transfer research.

Some *process issues* were also identified with respect to testbeds: lack of clarity on how researchers get innovations into testbeds; the observation that more information on proposal processes is needed. Are they different for all testbeds, or similar to DTC, which takes proposals all year round? Others noted *misalignment* between testbed priorities/commitments and research grant awards—some coordination is recommended, and Readiness Levels 5-7 projects were suggested as being appropriate to testbeds**.** Again, a smoother process for the incorporation of physics schemes from the research community also appeared in these discussions. In summary, testbeds should be the best place where non-NOAA entities (private and academic) can go to test new products/algorithms; *testbeds should be a stepping-stone to a proving ground.*

Process-related Issues

The *process of transitioning research components into operations* needs to be more robustly *well-defined*—the priority being on *how* transition takes place. The example offered was incorporation of a new microphysics scheme (e.g. Thompson) during testing of the new FV3 core. Transition plans need to be coordinated jointly between entities. The complex process of setting requirements is viewed as a roadblock. There was a view that incremental and safe changes are favored, but cutting-edge improvements are impeded—or at least that *perception* is an outcome of current practice. This process issue may be additionally complicated by varying research funding mechanisms, and requirements within both OAR and the NWS, which argues for a more unified approach across all of NOAA.

Generally, the *pace of implementation* between research and operational environments is perceived as being too slow. Though a few of the presentations cited examples of solutions to problems that could be implemented in months vs. years, these seem to be relatively few in number; or the visibility/awareness of those transitions is simply not evident. This perception of too-slow-a-pace seems to apply to *modeling advances* and *data assimilation techniques* especially.

Room for improvement is seen in *validation and verification processes*, with need for a more *systematic approach* ("what metrics are being verified across all operational systems using object-based approaches in addition to standard practice?"). This was identified by more than one group: the need for new *verification systems and techniques*; and *quality control issues:* "Evaluations are still science-based and outcome-based…*not decision-based, not impact-based, not agent-based, not process-based, does not involve big data."*

Training issues are challenges: forecaster time limits are problematic: there is too much data to digest; it is difficult to learn new products, or to play around with valuable information. More training in Git and GitHub were identified as challenges. Training should not be a *one-and-done approach*.

Clarity is needed regarding the *metrics used for evaluation* of transition plans, in R2O. And, as discussed above in the identification of HPC access as an issue, much of the process around high performance computing seems to be lacking, including little to no feedback, and difficulty in access.

General communication processes need improvement. Points of contact are needed in operations, for quality assurance and quality control, for logistics and technical requirements, all cited.

Social Science Issues

These issues are best described as *gaps in understanding*: these include perceptions and misperceptions; communication issues; differing incentives between research and operations communities; funding or resource limitations; and a generalized concern, or discomfort in some cases, with existing O2R2O implementation as being *inflexible, limiting, and not agile.* The need for *fostering of culture change* enabling and more effectively supporting R2O collaboration between academic research communities and operational communities was reflected in all the break-out groups.

There is a social science component around the projected implementation of tools like Warn-On-Forecast and FACETs, which take a probabilistic vs. deterministic approach to forecast. These are public facing, and will require social science research-based understanding of 1) how to best communicate high threat, but low probability events, and 2) understanding of how people process forecast/warning data and information. What are the verification systems and techniques, the needed metrics, underlying that communication?

There is a social science aspect to *forecaster training processes* as well: forecasters can benefit from training in communication and applying the processes of communication that can increase a sense of trust in forecast reliability—back to the issue of how people process understanding of data and information. This is also apparent in the comment that differences in interpretation of content or products can be an issue.

It was evident in discussion groups that there is a gap between operational and academic research communities when it comes to *incentivizing collaboration and the integration of R2O*. There needs to be clear understanding of gain in R2O for each community. While workforce recruitment and retention can be an issue across both communities, e.g. where there is little chance for promotion, or training, or an infusion of new ideas, there are going to be barriers to effective R2O. Operations, by its very nature, has inherent barriers of time and availability. The tenure priority for academicians is *publication,* and research academicians do not feel that priority for them is considered, and do not necessarily feel incentivized to go into the R2O process. This was an issue cited across groups. The promise or outlook for retention, new team involvement, and rewarding collaboration seems to work well within Cooperative Institutes and Cooperative Science Centers, where there is collocation of NOAA and research communities. Creating similar environments across NOAA R2O goals might find a starting point with the observation made by one group that "Testbeds should be the best place where non-NOAA entities (private and academic) can go to test new products/algorithms," and "*Testbeds should be a stepping-stone to a proving ground."*

Other observations identified as challenges to collaboration include a perception that basic research will be unsupported; possibly related to or a reflection of NOAA's very targeted opportunities and calls; the fact that NOAA staff travel is curtailed limits exposure to new ideas; and perceptions that both science priorities, and funding are limited. Some of the recommendations around improvements in Testbed utilization might be applicable to more effective collaboration. Another related recommendation, for *data gap issues* both technical and social: involve more outsiders/academics by promoting *Integrated Personnel Assignments* (IPA) to meet resource limitations.

Questions for both the operational and research communities going forward include further examination of possible *shared metrics in R2O*; how might these collaborations be evaluated, and what can each community do to incentivize or make collaboration easier? What should the research community know, to make things easier for operations to participate? How can the operational community be more effectively involved in innovative research? Is it viable to do assessments about when/where/how/what works between operations and research? and at what levels? When does it make sense to go fully for national implementation of an advancement? Is a more regional approach to implementations more effective? Are there *levels of implementation* that make sense?

Appendices:

Appendix 1: Workshop Agenda
Appendix 2: Detail of Break-out Group Responses
Appendix 3: Final Participant List
Appendix 4: Organizing Committee

Appendix 1 – Workshop Agenda

BUILDING A WEATHER-READY NATION BY TRANSITIONING ACADEMIC RESEARCH TO NOAA OPERATIONS

A Workshop

November 1-2, 2017

Goal: An informed academic community that actively participates in transitioning research to operations (R2O) and operations to research (O2R) to build a Weather-Ready Nation through improvements in NOAA's weather operations.

Objectives:

(1) To inform the academic community about NOAA's transition policies.
(2) To promote best practices for effective transitions of research from academia and NOAA.
(3) To explain NOAA's weather transition programs.

Venue: NCWCP Auditorium and Collaboration Rooms

8:00 am Network/Beverage service

8:30 am Welcome/introduction
- John Cortinas, OAR
- Gary Matlock, OAR
- Antonio Busalacchi, UCAR
- Mary Erickson, NWS

Session 1: NOAA Transitions: Overview, status and opportunities

9:00 am Overview of NOAA Transitions, Gary Matlock, OAR
- Fundamental concepts about transition at NOAA

9:30 am Review of progress in NOAA transitions, Hendrik Tolman, NWS, and Derek Parks, OAR
- Review academy report and assess progress
- Intellectual property and licensing

10:00 am Funding opportunities for NOAA transition, Fred Toepfer, NWS, and John Cortinas, OAR

10:30 - 10:50 BREAK

Session 2: Promises and challenges of R2O

A series of presentations focusing on the needs, requirements, gaps, successes and challenges of NOAA transition

10:50 am	Observations and instrumentations for NOAA operations, Joe Pica, NWS
11:20 am	NCEP production suite: current status and future evolution, Hendrik Tolman and Fred Toepfer, NWS
11:40 am	Social science aspects of NOAA operations, Gina Eosco, Cherokee Nation Company

12:00 - 1:00 Lunch

1:00 pm	R2O in satellite observations, Steve Ackerman, University of Wisconsin
1:20 pm	R2O in weather modeling, Robert Fovell, SUNY Albany
1:40 pm	The National Water Model: from Research to Operations, Tom Graziano and Ed Clark, NOAA/OWP
2:00 pm	Jerad Bales, CUASHI, R2O Experience on the National Water Model, Research Perspective
2:20 pm	The roles of NOAA labs and Cooperative Institutes in NOAA Transitions, Jennifer Mahoney, OAR
2:40 pm	NOAA R2O through Cooperative Science Centers, Reza Khanbilvardi, City College of New York

3:00 - 3:20 break

3:20 pm	R2O beyond weather example: wave models and NOPP, Arun Chawla, EMC
3:40 pm	R2O in climate, Dan Barrie, OAR

Session 3: Support for O2R

Presentations focusing on the support of operational systems to the research community

4:00 pm	DTC activities in support of O2R2O, Bill Kuo, Developmental Test Center (DTC)
4:20 pm	JCSDA activities in support of O2R2O, Tom Auligne, Joint Center for Satellite Data Assimilation (JCSDA)

Session 4: Open discussion & Set-up of Working Groups

4:40 pm Set-up the working groups

Thursday, 2 November

8:00 am Network/Beverage service

Session 5: Working Group discussion:

Participants will be broken up into smaller groups (10-15 people in a group) to:

1. identify the issues, and challenges, and
2. provide recommendations.

Questions for the breakout sessions:

1. From your or your organization point of view, what area of weather has matured research that has not transitioned to NWS operations? For example, new observational techniques, numerical modeling techniques, data assimilation techniques etc. Can you list two or three R2O priorities that you think NOAA should focus in the next five years?
2. What are some of the biggest gaps in the current weather forecasting that NOAA needs to focus on transitioning in order to fill these gaps in the next five to ten years?
3. From the perspective of your organization, what is the biggest challenge your organization faces in transitioning research to operations, other than the funding issue.
4. Testbeds play a crucial role in transitioning research to operations. Do you know anything about the testbeds? Are the current testbeds serving the intended purpose? Are they readily accessible to the academic and private sector?

8:30 - 10:00 Working Group discussion -

10:00 - 10:20 Break

10:20 - 12:00 Working Group discussion -

12:00 - 1:00 Lunch

Session 6: Working group reports

1:00 - 3:00 Reports from working groups

3:00 - 3:20 Break

Session 7: Wrap - up and next steps

3:20 - 4:20 Wrap-up and next steps 4:20 Meeting adjourn

Appendix 2 – Detail of Break Out Group Responses

O2R2O Meeting Break out groups explored four common questions resulting in identification of the primary priorities, gaps and challenges present in weather related research and operations.

Questions

5. From your or your organization point of view, what area of weather has matured research that has not transitioned to NWS operations? (For example, new observational techniques, numerical modeling techniques, data assimilation techniques, etc.) Can you list two or three R2O priorities that you think NOAA should focus on in the next five years?
6. What are some of the biggest gaps in current weather forecasting that NOAA needs to focus on transitioning in order to fill these gaps in the next five to ten years?
7. From the perspective of your organization, what is the biggest challenge your organization faces in transitioning research to operations, other than the funding issue?
8. Test beds play a crucial role in transitioning research to operations. Do you know anything about the NOAA test beds? Are the current test beds serving the intending purpose? Are they readily accessible to the academic and private sector?

The output from all group has been aggregated below and color-coded: **Group 1**; **Group 2**; **Group 3**; **Group 4**.

Question 1

Part 1: Matured research not yet transitioned to NWS operations
Part 2: R2O Priorities for next five years

Q1 Part 1 – Research not transitioned – GROUP 1:

1) Algorithms developed for GOES16 and GLM - "on the bridge," but not into operations yet, why is that?
2) Vegetation index, cloud properties, total ozone, low cloud and fog, visibility index, sea ice concentration.
3) Need a systematic and controlled approach to advance FV3 Physics packages.
4) Robust verification and calibration: a systematic approach to verification (what metrics are being verified across all operational systems?) using object-based approaches in additional to standard practice (i.e., 500-hPa anomalies).
5) Data assimilation (DA) methods:
    i. European Centre for Medium-range Weather Forecasts - ECMWF is celebrating *20 years of 4DVar*. Other operational centers have implemented advanced DA techniques; why don't we?
    ii. System/computer optimization.

Q1 Part 1 – Research not transitioned – GROUP 3:

6. *Aviation forecast:* Five different verification techniques and systems have been put on hold because of funding; at RL8.
7. *Warn-on Forecast* – RL7 – warning of high impact weather; is ensemble-based, high resolution, high update forecast system (every 15 min). Has been tested in a relevant environment (weather test bed). *Tentatively scheduled for implementation in 2022.*
8. *FACETs – Forecasting Continuum of Environmental Threats* - proposed next-generation severe weather watch and warning framework.
9. *Coupled techniques or systems for sea ice*.
10. *Radio occultation* already mature – but quantity of data may be an issue. Question about ability to get enough high-resolution data via current satellite resources.

Q1 Part 1 – Research not transitioned – GROUP 4:

11. Coastal ocean modeling
    a. Not physics or software, but rather research knowledge/tools that can be used in operations
12. Urbanized high-resolution modeling
13. Leverage community multi-model ensembles, especially on longer time scales not currently being examined
14. Hydrological inundation modeling, complementing/extending what NWC is doing

----

Q1 Part 2: Priorities – GROUP 1:

1) Systematic and controlled approach to advance FV3 Physics Packages:
   a) Smoother process to incorporate other physics schemes from research community (e.g., Thompson, Morrison, RRTMPG).
2) More generally, the process of transitioning research components into operations:
   a) Need a well-defined process of how that transition takes place, which isn't trivial.
   b) Example: Incorporating developers of a microphysics scheme (e.g., Thompson) during testing of the new FV3 core.

Q1 Part 2: Priorities – GROUP 2:

Group 2 aggregated their responses to the two-part Question 1 into a single response, as priorities:

3) Ocean modeling/monitoring
4) Urban climate
5) Social/behavioral science

`

Q1 Part 2: Priorities – GROUP 3:

6) *Warn-on Forecast* (RL 7) to increase tornado, severe thunderstorm, and flash flood warning lead times, and *FACETs* – proposed next-generation severe weather watch and warning framework: ensemble-based, high resolution, high update forecast system (tentatively scheduled for implementation in 2022). High public awareness impact and a change in the way forecast services are done, from deterministic to more of a probabilistic approach.

7) *Coupling techniques - Modeling and data assimilation improvements:* (RL 6); scale-aware physics (parameterizations) to unified model goals within 3 years; Radio Occultation-derived soil moisture.

8) *Data-based elements: Observations and Validations:* New verification systems and techniques; Dissemination of data due to quality control issues (MADIS latency issues) and data volume issues; satellite derived sea-ice and snow depth.

Q1 Part 2: Priorities – GROUP 4:

Group 4 aggregated their responses to the two-part Question 1 into a single response, as research-not-transitioned (see Q1, Part 1)

Question 2 - Biggest Gaps in Modeling

Q2: Gaps – GROUP 1:

1) Global model not up to the standards of the European Center for Medium-Range Weather Forecasts (ECMWF).

2) Coupled atmospheric modeling (land, ocean, etc.).

3) DA and community-developed DA:
    i. Coupled DA?
    ii. Under-dispersive ensembles

4) Training forecasters in local offices.

5) Interpretation of content/products being created.

6) Data infrastructure gaps.

Q2: Gaps – GROUP 2:

7) Data requirements to understand sub-grid scale processes.

8) Air-land, land-water, water-air coupling.

9) Ensembles and probabilistic Information.

10) Commitment to reforecasting.

11) Automation and role of humans.

Q2 – Gaps – GROUP 3:

12) *UAS platforms* have been used over the sea but there are severe limitations over land by the FAA.

13) *Modeling techniques* gaps*:*
    i) Modeling techniques for a unified model framework and evaluating the FV3 model numerics and boundary conditions.
    ii) Tropical Cyclone track, intensity, structure – why is there a gap with ECMWF and our forecasts?
    iii) Contribution of other global model communities.
    iv) Coastal inundation – a coupled modeling problem as well as rapid intensification of land-falling hurricanes (need more seamless transition between modeling at landfall).
    v) S2S – sub-seasonal to seasonal techniques.
    vi) *Data latency issue with forecast*: a distinction was pointed out between *assimilation of data* (because of not meeting quality control standards) and *observations/disseminations of data.* Some mesonet data can take 30 minutes, when the goal is to update forecasts in five-minute intervals.

Additional gaps beyond modeling:

14) *HPC Gap*: Research computing should be greater than operational computing, but it is currently the opposite. The research computing resources need to increase in order to move forward.

15) *Public dissemination, and therefore social science implications:* FACETs: Focus on providing warning on an envelope of probability instead of a "warning" vs "watches" hard approach; QPF improvements that would detail the specific types of precipitation for different locations. How do you communicate low probability, but high threat events? WFO Forecast paradigm shift.

16) *Air quality and Fire Weather*

17) *PBL* and *soil moisture data gaps*

Q2 – Gaps – GROUP 4:

18) "'Tuning' can produce a better forecast tomorrow, but for long-term improvement, enhanced physics understanding is needed … and these goals conflict" (H. Tolman)

19) Evaluations are still science-based and outcome-based…
    a. not decision-based, not impact-based, not agent-based, not process-based, does not involve "big data."
    b. Forecast accuracy is not enough; need different/new metrics
    c. Partly a social science problem. *How do people process forecast/warning data?*

20) Data/resources available at universities (e.g., observations, hi-resolution models, ensembles) could be "certified" in some way to facilitate.

21) Survey forecasters: what are they using?

22) Warning: exponential growth in data being generated, but at the end decisions is a "small spigot."

23) ECMWF far along on developing fully coupled global forecast systems; we need to work on this too.

24) Data needed to supply those coupled systems need to be supported.

25) Target specifically data sparse regions.

26) Involve more outsiders/academics: promote IPA (Integrated Personnel Assignment) route.

27) NOAA staff travel curtailed – limits exposure to new ideas.

Question 3 – R2O Challenges Facing Our Organizations

Q3 – R2O Challenges – GROUP 1:

1) High Performance Computing (HPC) resource limitations:
    i. Non-uniform HPC environments across NOAA.
    ii. Hard to get allocations/accounts on NOAA HPC resources (academia).
    iii. Transitions of upgrades are difficult.

2) Availability of validation datasets:
    i. Need to make apples-to-apples comparison with operational systems but those large datasets are not available.
    ii. Restricted vs. non-restricted data problems.

3) Forecaster time limits:
    i. Too much data for them to digest.
    ii. Hard to learn new products or "play around" with valuable information.

4) Documentation
    i. Up-to date information is hard to find; Example: how does GFS treat near surface ocean temp?
    ii. Code repositories and clean rules of engagement are needed.

Q3 – R2O Challenges – GROUP 2:

5) Incentives: for researchers and operations

6) Science Priorities

7) Funding

8) Who on operations
    a. Points of contact
    b. QA/QC
    c. GPRA Goals
    d. Logistics & technical requirements

9) Proposal process.

10) External grantees not connected to NOAA.

11) People/culture change.

Q3 – R2O Challenges – GROUP 3:

12) Perception: Basic research will be unsupported.

13) Coding infrastructure commonality for the ease of transition onto operational systems. Subversion code development and Git/Github training.

14) Workforce recruitment, promotion, training, retention for CIs and CSCs, NOAA, universities. Need incentives such as retention, new team involvement. Tenure priority is publications and professors are not incentivized to go on the R2O process.

15) Transition plan needs to coordinated jointly between entities
    a. NOAA consistency needed and it should be detailed.
    b. Complex process of setting requirements is a roadblock.
    c. Incremental and safe changes are favored, but cutting-edge improvements are impeded.

16) Leveraging of private sector resources.

17) HPC Resources: lack of access (we are 26-32 times behind what is needed by 2020); Transition issues between different HPC systems.

Q3 – R2O Challenges – GROUP 4:

18) Problem: software compilation and dependencies. Solution: containers (Docker)

19) Problem: difficult to add/evaluate new physics. Solution: CCPP

20) Problems relating to computing:
    a. HPC access - computing available for research has lagged to that available to operations, by large margin; huge issues with NOAA HPC access.
    b. Can't replicate information streams used in operations off-site.
    c. Code optimizations needed for operational performance often break portability for research purposes; causes code divergence.
    d. Our data storage and availability are stuck in a 1980s model; need to bring users to the data, facilitate modern big data approach, use server-side computing/thin client model.

21) Clarity needed regarding metrics used for evaluation of transition plans.

22) Proposal reviews may be biased or not considered holistically.

23) Integrating social science component from the start, from multiple social science perspectives, methodologies.

Question 4 - Testbeds: Are they serving their purpose?

Q4 – Testbeds – GROUP 1:

1) Move to cloud-based computing.
2) How do we structure the testbeds to support a unified-modeling system?
3) Devise a global-model testbed that covers more than just the atmosphere; currently, there is no mandate to look at global earth-system models beyond atmosphere.
4) End-to-end testbed in that it mimics an operational environment.
5) How do researchers get innovations into the testbed?
6) Testbeds appear to meet their purpose, generally.
    a. Ex: Many academic partners are in the Hazardous Weather Testbed Experimental Forecast Program.

Q4 – Testbeds – GROUP 2:

7) Researchers don't know about Testbeds and their core goals.
8) Perceptions include:
    a) Testbeds are narrowly focused.
    b) Doesn't feel like there is an open invitation.
    c) Is who you know / a boy's club.
9) Proposal process.

Q4 – Testbeds – GROUP 3:

10) Awareness of the testbed functions is limited to the communities to which a testbed caters.
11) Testbeds are functional, but their computer resources are limited. They are retrospective; operational use is limited; each use has a specific need, but data is missing in some cases. Feedback is limited.
12) RL5-7 is recommended. *The testbeds should be a stepping-stone to proving ground.* Testbeds should be the best place where non-NOAA entities (private and academic) can go to test new products/algorithms.
13) Need a smoother process to incorporate physics schemes from the research community.

Q4 – Testbeds – GROUP 4:

13) Many TBs, wide range, so difficult to deduce common problems and solutions.
14) Misalignment between testbed priorities/commitments and research grant awards.
15) TBs not widely visible.
16) Faulted for not providing adequate feedback in some instances, being too inflexible, not very responsive.

Appendix 3 - O2R2O Participant List

Building a Weather Ready Nation by Transitioning Academic Research to NOAA Operations - A Workshop

November 1-2, 2017
Greenbelt, Maryland

	Last name:	First name:	Organization/Affiliation:
1	Ackerman	Steve	University of Wisconsin-Madison
2	Adams	Terri	Howard University
3	Akede	Elizabeth	NOAA
4	Alexander	Curtis	NOAA/ESRL/GSD
5	Anderson	John	Hampton University
6	Apodaca	Karina	Colorado State University/CIRA at NOAA/OAR/ESRL/GSD/GOSA
7	Aulígné	Thomas	JCSDA
8	Baker	Debra	CICS-MD, University of Maryland
9	Bales	Jerad	CUASHI
10	Bao	Shaowu	Coastal Carolina University
11	Berbery	E. Hugo	CICS/ESSIC, University of Maryland
12	Bernardet	Ligia	NOAA GSD and CU/CIRES
13	Andrea	Bleistein	NOAA NWS
14	Busalacchi	Antonio	UCAR
15	Carlis	DaNa	NOAA
16	Carman	Jessie	NOAA/OAR/National ESPC
17	Cash	Benjamin	GMU/COLA
18	Chawla	Arun	NCEP
19	Chu	Philip	NOAA/GLERL
20	Clark	Ed	NOAA
21	Colle	Brian	Stony Brook University
22	Cortinas	John	NOAA
23	Crowley	Michael	Rutgers University

24	Christopher	Davis	NCAR
25	DeAngelo	Benjamin	NOAA Climate Program Office
26	DeGraw	Kyle	University of Maryland AOSC
27	Deheza	Veva	NOAA - NIDIS
28	Delgado	Ruben	UMBC
29			
30	Dennis	Eli	CICS-MD
31	Doss-Gollin	James	Columbia University
32	Dunlap	Rocky	NOAA/ESRL
33	Eosco	Gina	CNSP support to NOAA Office of Weather and Air Quality
34	Erickson	Mary	NOAA / NWS
35	Fan	Jia-Fong	Howard University
36	Farnham	David	Columbia University
37	Fisher	Kalen	Howard University
38	Fitzpatrick	Pat	Mississippi State University
39	Fovell	Robert	University at Albany
40	Fulton	Richard	NOAA/OAR Office of Weather and Air Quality
41	Gerard	Alan	NOAA/OAR/NSSL
42	Glenn	Scott	Rutgers University
43	Goldhaber	Steve	NCAR
44	Gonzalez	Jorge	The City College of New York/NOAA-CREST
45	Graziano	Thomas	NWS/ NOAA
46	Hartman	Robert	UCSD / SIO / CW3E
47	Henderson	John	AER
48	Higgins	Wayne	Climate Program Office / OAR / NOAA
49	Hill	Aaron	Texas Tech University
50	Hopson	Leah	CICS-MD, University of Maryland
51	Huang	Jin-Luen	CPO / NOAA
52	Iacono	Michael	AER
53	James	Carl	OAR/OWAQ
54	Jeong	Inseong	NOAA/NOS

55	Johnson	Bradford	OAR/OWAQ
56	Johnson	Benjamin	UCAR/JCSDA
57	Jones	Thomas	CIMMS / NSSL
58	Kayo	Ide	University of Maryland
59	Kebede	Mussie	Howard University
60	Kelleher	Kevin	NOAA/OAR/ESRL/GSD
61	Khanbilvardi	Reza	NOAA-CREST Center at City University of New York
62	Koch	Steven	NOAA/OAR/NSSL
63	Kondragunta	Chandra	NOAA/OAR/OWAQ
64	Kuo	Bill	DTC
65	Kurkowski	Nicole	NWS/OSTI
66	LaDue	Daphne	University of Oklahoma
67	Lakhankar	Tarendra	NOAA-CREST Center
68	Lall	Upmanu	Columbia University
69	Large	William	NCAR
70	Lee	Jin-Luen	Spire Global Inc. Boulder
71	Lukens	Katherine	CICS-MD, University of Maryland
72	Mahoney	Jennifer	NOAA/ESRL/GSD
73	Matlock	Gary	DOC/National Oceanic & Atmospheric Administration
74	McCambridge	Michelle	UCAR / CPAESS
75	McFarquhar	Greg	Cooperative Institute for Mesoscale Meteorological Studies
76	McIlvain	Eileen	CPAESS
77	McVey	Kerri	CICS-MD, University of Maryland
78	Melecio-Vazquez	David	The City College of New York/NOAA-CREST
79	Merchant	Shakila	NOAA CREST, The City College of New York
80	Miles	Travis	Rutgers University
81	Morton	Don	Boreal Scientific Computing, Fairbanks, Alaska, USA
82	Moses	Chris	NOAA/OAR

83	Myrick	David	NWS/STI
84	Nance	Louisa	NCAR
85	Olayinka	Kafayat	Howard University
86	Opatz	John	NOAA/OWAQ
87	Ortiz Uriarte	Luis	The City College of New York
88	Parks	Derek	NOAA
89	Pica	Joseph	NOAA / NWS
90	Rao	Yuhan	CICS-MD/GEOG, University of Maryland
91	Romine	Glen	NCAR
92	Sanders	Shadya	Howard University
93	Satya	Kalluri	NOAA/NESDIS/STAR
94	Smith	Stephan	NWS/OSTI/MDL
95	Straus	David	COLA/George Mason University
96	Stunder	Barbara	NOAA OAR Air Resources Laboratory
97	Tallapragada	Vijay	NOAA/NWS/NCEP/EMC
98	Toepfer	Fred	NGGPS / NWS
99	Tolman	Hendrik	NOAA / NWS / OSTI
100	Tribbia	Joseph	NCAR
101	Vertenstein	Mariana	National Center for Atmospheric Research
102	Wang	Zhuo	University of Illinois at Urbana-Champaign
103	Whitcomb	Timothy	Naval Research Laboratory
104	Wilkinson	Ayesha	NCAS Howard University
105	Yussouf	Nusrat	CIMMS/OU/NSSL
106	Zhang	Yu	U of Texas at Arlington

Appendix 4 - Organizing Committee

Building a Weather-Ready Nation by Transitioning Academic Research to NOAA Operations

Workshop

November 1-2, 2017
College Park, MD

John Cortinas, NOAA/Office of Atmospheric Research (OAR), Co-Chair

Bill Kuo, University Corporation for Atmospheric Research (UCAR), Co-Chair

Reza Khanbilvardi, City College of New York

Chandra Kondragunta, NOAA/OAR

Jennifer Mahoney, NOAA/Earth Systems Research Laboratory (ESRL)

Fred Toepfer, NOAA/National Weather Service (NWS)

Hendrik Tolman, NOAA/National Weather Service (NWS)