Testimony of

DR. PETER P. NEILLEY, THE WEATHER COMPANY, AN IBM BUSINESS

to

THE SUBCOMMITTEE ON ENVIRONMENT

of

THE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

of

THE UNITED STATES HOUSE OF REPRESENTATIVES

Hearing on

"A TASK OF EPIC PROPORTIONS: RECLAIMING U.S. LEADERSHIP IN WEATHER MODELING AND PREDICTION"

NOVEMBER 20, 2019

Introduction

Chairman Fletcher, Ranking Member Marshall, and Members of the Subcommittee - good morning and thank you for the opportunity to address the subcommittee today. My name is Dr. Peter P. Neilley and I am the Director of Weather Forecasting Sciences and Technologies at The Weather Company (TWC), an IBM Business. I oversee a team of scientists and engineers that develop a broad suite of technologies, including numerical weather prediction (NWP), that are used to create and distribute weather products and services for our business. We serve a global footprint of individuals and businesses through our branded products, including The Weather Channel, weather.com, and Weather Underground, through a variety of global business specialized products serving the aviation, energy, retail, insurance, transportation and agriculture markets, as well as through our distribution partners including Apple, Google and Facebook. We routinely distribute over 30 billion forecast products each day to an estimated 1-2 billion individual daily users worldwide. Our core weather products are created from a proprietary forecast production engine that is heavily dependent on our own internal NWP capabilities and on the output of NWP models operated by the National Oceanic and Atmospheric Administration (NOAA) and other international weather services.

In addition to my role at TWC/IBM, I have served or actively serve on a number of committees, working groups, and advisory boards involved in the development and creation of weather forecasting sciences and services. This includes past chairman of the American Meteorological Society (AMS) Committee on Weather Analysis and Forecasting, as well as service on numerous NOAA-related committees and working groups including EISWG[1], UMAC[2] and as co-chair of UCACN.[3] More recently I am serving on the Environmental Predication Innovation Center's (EPIC's) Community Workshop organizing committee. I understand EPIC is the subject of today's hearing and the focus of my comments herein.

My interests in advancing NWP capabilities for the nation are rooted in a deep, personal, and visceral interest in the betterment of weather forecasting to serve society, as well as a professional interest in creating superior weather products for TWC/IBM. It is from both perspectives that I address the subcommittee today. I also believe my testimony is largely consistent with the summary findings of the EPIC Community Workshop Organizing Committee presented at the end of the workshop held this past August.

State of NWP in the United States

The U.S. has the largest, broadest, and most diverse NWP community in the world, with activities occurring in several federal agencies (including NOAA, NASA, DOE, and DoD), numerous national laboratories, a large number of academic institutions as well as a growing number of commercial enterprises. As a result, we have a broad set of national NWP capabilities, often tailored to the needs of the specific institution hosting the activities.

Unfortunately, there is no unified national strategy that guides the investments in, development of, or operation of NWP across the nation. While diversity in scientific advancement is a good thing, the extreme diversity and breadth of NWP activities across the nation has actually led to underperformance in most of our NWP capabilities. Our nation's uncoordinated approach to NWP has resulted in broad capabilities that are good, but often not great. As a result, our nation is significantly underprepared for, and less resilient to, the impacts of weather and climate on our lives, economy and national security.

The issues identified above are also reflected at NOAA and the National Weather Service (NWS). NOAA has a history of insular NWP development, creating and deploying a broad portfolio of NWP models that has led to operational capabilities that are often less accurate than some international counterparts, a result that has been widely analyzed and reported for decades. Fortunately, there have been considerable efforts by NOAA over the past several years to simplify its NWP portfolio and to seek new NWP capabilities from the broader community. The NWS's implementation of the High-Resolution Rapid-Refresh model based on a model developed by the National Center for Atmospheric Research (NCAR) now represents the world standard in short-term (under one day) operational NWP. More recently, the NWS has transformed the heart of its global medium-range (1-15 day) Global Forecast System (GFS) from an aged, home-grown model to one first developed at Princeton University (the Finite Volume Cubed Sphere, or FV3). This transformation is part of the Next Generation Global Prediction System (NGGPS) program and the cornerstone of NOAA's Unified Forecast System (UFS). It holds promise in reducing the accuracy gap between NOAA's global modeling capabilities and the current standard established by the European Range

[1] EISWG is the Environmental Information Services Working Group, a standing working group of NOAA's Science Advisory Panel.
[2] UMAC is the UCACN Model Advisory Committee.
[3] UCACN is the UCAR Community Advisory Committee for NCEP. UCAR is the University Corporation for Atmospheric Research and NCEP is the National Centers for Environmental Prediction, one of the major divisions of the National Weather Service.

for Medium Range Weather Forecasting (ECMWF). However, alone it is likely insufficient to achieve or sustain NWP superiority for the nation.

A Collaborative Approach to NWP Superiority

While the recent NWP modernization efforts at NOAA are encouraging, they represent only a small fraction of what NOAA and this nation could achieve with a more coordinated and holistic approach to NWP development and deployment. Stakeholders and participants across the NWP community have agreed on this for more than a decade, and it has been reflected in numerous studies and reviews. This approach would create new paradigms, institutions and cooperative cultures that foster collaborative, efficient and effective NWP development across the nation. It would also create processes by which the broader NWP community can rapidly inject scientific and technical advancements into operational weather forecasting at NOAA and elsewhere.

There is substantial evidence that a broad collaborative approach to NWP development can result in superior NWP operational capabilities. For example, NCAR's WRF-ARW, MPAS, and CESM models are widely regarded as one of the world's best models for regional, global, and climate NWP, respectively. Each model has a large, vibrant community of active users and developers that contribute to the overall efficacy of the models. These communities represent all facets of the weather enterprise, including those that wish to use models for operational NWP purposes and as instruments to advance the atmospheric sciences. The communities have flourished not because of specific-funded initiatives to help develop the models, but rather because the modeling systems represent state-of-science capabilities that are highly attractive to researchers and users. The communities exist because of the modeling capabilities, and not necessarily to develop the model. However, the communities end up contributing to the advancement of the models, which in turn attracts even more members to the community.

Despite the long-held vision that a more community-oriented approach to advancing NOAA's NWP capabilities is needed, and despite some of the advancements NOAA has made recently, it remains difficult for external scientists to participate in advancing NOAA NWP. Three of the more significant barriers are:

- Inaccessibility to the model codes and the required infrastructure to assist in understanding and using those codes.
- Limited processes by which advancements from the community can easily be incorporated into the NOAA models. The new UFS governance approach to NOAA's global modeling is a step toward improvement but is still far from optimally effective.
- Insufficient access to suitable computational resources to develop, test, and run the codes.

As a result, participation in the advancement of NOAA's modeling capabilities is limited to a relatively small set of developers that have inside, privileged, or unique access. Outside participation in NOAA NWP development is relatively minor compared to the participation levels of the NCAR WRF, MPAS and CESM communities mentioned earlier. As compared to entities such NCAR, NOAA is less experienced and has fewer tools available to it to establish and manage a community of participants for NWP development.

EPIC: A Generational Opportunity

Under the leadership of Acting NOAA Administrator Dr. Neil Jacobs, NOAA has realized the need to create new paradigms for more effective infusion of external science and capabilities into its modeling portfolio. The Environmental Prediction Innovation Center (EPIC) concept proposed by Dr. Jacobs represents a unique, generational opportunity to dramatically improve NOAA's and the nation's overall NWP capabilities by creating an institution that enables, catalyzes and entices broad participation in a common NWP R&D process. The EPIC vision is strongly aligned with the decades of recommendations about improving the NWP capabilities for the nation. Given the strong alignment of the community around EPIC, and the support for it from the leadership at NOAA, there is a unique opportunity to make the most substantial improvements in the NWP capabilities for NOAA and the nation in a generation.

If successful, EPIC will not only provide the nation with the world's most accurate weather and climate forecasts, it will also significantly advance the NWP capabilities of all the other institutions involved in NWP including NASA, DoE, DoD, national laboratories, NCAR, academic institutions, and private enterprise. This broader improvement beyond just NOAA is perhaps the larger payoff for EPIC to the nation, and it is imperative that our nation seizes this opportunity.

There are at least two approaches to how NOAA could design EPIC to advance its engagement with the broader community. In the first approach, NOAA could identify the specific scientific advancements needed, and methods to development them, and then frame EPIC around those requirements. Alternatively, NOAA could establish EPIC with a much broader and holistic approach to NWP improvements that would catalyze the broadest possible creativity and advancements in NWP, with a subset of the best and most relevant of those advancements imported into NOAA NWP capabilities. The first approach would represent an extension of the status quo methods of NOAA engagement with the community, a model that has clearly not resulted the NOAA having the best modeling capabilities. The second approach results in a pipeline of scientific and technical advances that can far exceed the predetermined, more narrow new capabilities NOAA would otherwise have identified. Evidence from experiences to date suggest that broader catalytic approach to engaging with the community will result in a substantially more effective end result for NOAA than the narrow, focused and tightly managed approach.

Essential to the success of EPIC is the breadth and diversity of participants in the EPIC community. In order to achieve this, the following characteristics of EPIC are critical:

- The fundamental mission of EPIC must be for the betterment of NWP, and not narrowly focused on the immediate and future needs of the NOAA. The science advancements within EPIC should support a broad set of NWP activities, a subset of which will have direct, material impact on NOAA's operational NWP capabilities.
- A broad set of NWP components, and not just the set of components currently or planned to be in operations at NOAA must be available and supported by EPIC. This includes dynamic cores, physics, data assimilation methods, and associated coupled models. This is critical to engaging the broadest community possible by creating a cauldron of scientific capabilities that entice users to participate.
- Strong partnership with related and adjacent institutions such as the Joint Center for Satellite Data Assimilation, the National Center for Atmospheric Research, and many of NOAA's cooperative institutes.

- EPIC must be a community-owned institution, operated outside of NOAA, and governed by and for the community. NOAA would be an important constituent in that community, but not the majority member.
- Details about the operation of EPIC, including governance, technologies, support structures (e.g. documentation, user help, etc.), technical processes (code management, testing procedures, computing allocation, etc.), funded research, and other subcontracts that facilitate its success, must all be determined by the managing structure of EPIC, and not mandated or micromanaged by NOAA. NOAA must cede authority for operating EPIC to the managing entity. Once established, NOAA's focus should be on deriving value from EPIC's accomplishments by reducing them to practice.
- The EPIC managing entity must be beholden and accountable for the success of EPIC. Bold measures of success should be established for EPIC and should include the breadth of community participation in EPIC, and the degree of improvement it delivers to the nation's NWP capabilities. Goals should include near term (1-2 years) and long-term (3+ years), with at least one near-term goal demonstrating the potential value of the long-term EPIC vision.

EPIC's success will mean bringing together a breadth of the nation's NWP activities under one umbrella. This umbrella must still allow for diversity of scientific creativity, but in an R&D framework that can reduce the most relevant and important achievements to operational capabilities for NOAA. To catalyze that participation, EPIC must create a capability that entices such participation, rather than one that directs it.

Although this new paradigm calls for NOAA to relinquish tight control on the organization, management, and operation of EPIC, it should not be taken that NOAA becomes a passive bystander. Rather, NOAA perhaps plays the most significant role of any one participant by:

- Participating as an active member in the science and technical development work within EPIC;
- Identifying the most promising and useful new science and technologies developed in EPIC and reducing them to practice inside its operational models;
- Ensuring the framework of the institution is designed in such a way to facilitate rapid reduction to practice of the new science and technologies developed in EPIC;
- Providing a flow of "operations to research" feedback to EPIC to help guide priorities for EPIC directed R&D;
- Serving as the primary federal agency supporting EPIC, providing sufficient funding to sustain it and assisting in the coordination with other federal stakeholders such as NSF and DoD.

Barriers to Success

There are several barriers to EPIC's success that will need to be addressed. These include:

- Compared to other entities like NCAR, NOAA has less experience and fewer tools needed to establish and manage a broad community of participants. EPIC represents a sea change in how NOAA advances its NWP capabilities and there will be institutional barriers as a result. A particularly important change is the need to delegate authority to an external entity to construct, manage and operate EPIC for NOAA and the community in order to optimize its efficacy and ability to deliver world-leading NWP capabilities back to NOAA. Both strong leadership within

NOAA embracing the EPIC vision as well as several near-term successes are critical in overcoming this barrier.

- As mentioned earlier, NCAR has already established the world's leading NWP scientific and technical communities around its regional, global and climate modeling systems. The size and reach of these communities are impressive, vastly larger than any other community modeling efforts in the world. It is essential that EPIC and these established communities unify otherwise there will be competing NWP development communities. For example, if in several years from now a graduate student seeking a modeling platform to assist in their thesis studies must choose been EPIC and the NCAR communities, rather than going to EPIC as the singular source of the superset of NWP technologies, then EPIC is likely to fall significantly short of accomplishing the potential of the vision outlined here. Since the NCAR communities are established and entrenched, it might be difficult for an upstart EPIC community to gain traction and critical mass unless it strategically integrates with the NCAR communities. Central to accomplishing that will be including the MPAS dynamical core in the EPIC modeling framework.
- NWP development and operations has always been significantly limited by the amount of high-performance computing (HPC) available to develop, test and run the models on. Some studies have estimated that the weather and climate NWP community has a need for up to 100 times the computing power currently available to it. Within the EPIC framework not all of the computing needed to conduct the breadth of science envisioned will be done using EPIC-provided compute resources. In fact, a majority of the computer resources may be provided by facilities otherwise available to participates in EPIC. These could range from a graduate student's laptop, to HPC facilities at major national laboratories. However, we should expect that EPIC will need substantial computing resources to support its permanent staff, and to allocate to a subset of its participating scientists. The EPIC managing entity should be given an initial modest budget (perhaps $5M) to establish foundational computing resources, and then quickly develop within its first year a long-term computing strategy and budget.

Congressional Support

EPIC represents a significant opportunity for the nation and major change that will substantially improve our nation's NWP capabilities. It is important that all stakeholders that have influence on, participation in, or dependence on EPIC outcomes embrace the vision, collaborate on its implementation, and participate in its activities. This includes Congress which should use the legislative power to foster EPIC's initial establishment and sustain its long-term durability as a national resource. The initial authorization of EPIC in the *National Integrated Drought Information System Reauthorization Act of 2018* was sufficient to get the establishment of EPIC started, but additional congressional support to ensure its success is needed. This includes:

- Encouraging federal agencies that participate in NWP development and operations, including DoD, DoE, NASA, and NSF to embrace EPIC as a national infrastructure that will aid the development of NWP capabilities in all sectors, not just NOAA, and to work to identify means by which those agencies can substantially contribute to, participate in, and benefit from EPIC.
- Direct NOAA to establish EPIC in the manner discussed herein, and in particular, to delegate authority to create, manage, and operate EPIC by an independent entity in a manner that entices community ownership and participation in the institution.

- Plan for long-term sustaining budgetary support for EPIC including base funding to support its permanent staff and facilities, ongoing research funding grants, and significant increases in computing resources. It is premature to gauge the exact level of the support needed. Determining long-term budgetary needs should be an early initial focus of EPIC's managing entity, but depending heavily on the computing, staffing, and facilities strategy that the EPIC managing entity pursues, annual EPIC costs would certainly exceed the initial appropriation and be recurring. This is ultimately a question for NOAA and EPIC to determine.

Summary

EPIC represents a singular, generational opportunity to elevate U.S. NWP capabilities to the best in the world by establishing a center of excellence that brings together the uncoordinated scientific and technical NWP developments found in all corners of the enterprise under one, unified umbrella. EPIC's success would not only ensure that NOAA will create the world's best weather and climate forecasting services for the nation, but it will extend those benefits to all other corners of the U.S. NWP community including other federal agencies, national laboratories, academic institutions and private enterprise. Doing so will optimize the resiliency of the nation to the impacts of weather and climate on our lives, livelihood, economy and national security.

Success of the EPIC opportunity critically depends on at least these factors:

- EPIC is founded as a national institution, set up and managed by an independent entity outside of NOAA, constructed and operated in manner that entices broad scientific and technical participation, and is beholden to delivering the world's best NWP capabilities back to NOAA and EPIC's other participants.
- Leadership in embracing EPIC by all sectors of the NWP community, including by leaders in NOAA and all other federal stakeholders involved in NWP.
- Sustained funding for EPIC, particularly for infrastructural staffing, facilities, research grants and computing.

Many of the country's primary operational NWP capabilities have underperformed relative to international counterparts for decades, partly as a result of a distributed, uncoordinated approach to its development and operation without an overall guiding national strategy or vision. EPIC represents the best opportunity in a generation to correct this and deliver to the nation superior weather and climate services that optimize the return on the investments the country is making in the science.

The Weather Company
An IBM Business
400 Minuteman Road
Andover, MA 01810

Phone 978-983-6554
E-mail peter.neilley@us.ibm.com

Dr. Peter P. Neilley

Overview

Dr. Neilley has about 30 years of experience in meteorology, mostly developing state-of-the-science technologies in weather forecasting for public use and weather-dependent markets. Dr. Neilley was a scientist at the National Center for Atmospheric Research between 1991 and 2001 conducting research on various aviation weather problems and the application of artificial intelligence methods for weather forecasting applications. He served as a principal scientist for a project to understand and predict terrain-induced and convective weather hazards in Hong Kong Airport and similar programs in Juneau and Colorado Springs. He was also the lead scientist developing an operational and automated weather forecasting system, derivatives of which are used today to drive forecasts consumed by billions of people daily. In 2001, Dr. Neilley became chief scientist at Weather Services International (WSI) Corp., leading a team of scientists developing methods for improved forecast technologies for a wide sector of markets. In 2007, Dr. Neilley became Vice President of Forecasting for WSI, responsible for both the research and operational forecasting including WSI's extensive aviation weather forecasting branch. In 2009, Dr. Neilley was promoted to Senior Vice President of Forecasting for The Weather Company, WSI's parent organization that includes The Weather Channel, weather.com, EEC Weather Radars (until 2012), Weather Underground and other holdings. In 2016, after The Weather Company's acquisition by IBM, Dr. Neilley was named an IBM Distinguished Engineer.

Dr. Neilley is active in the community and currently is co-chair of the UCAR Community Advisory Committee for NCEP that reviews and advises the National Weather Service on its core operational centers. He also served on the UCACN Model Advisory Committee for NOAA and more recently on the EPIC Summer Community Workshop planning committee. He recently completed a six-year tenure on NOAA's Science Advisory Board's Environmental Information Services Working Group where he was the principal author of the NOAA-adopted Open Environmental Information Services paradigm that contributed to the creation of the recent NOAA Big Data Initiative. He was a longtime member and chair of the American Meteorological Society's Committee on Weather and Forecasting and championed the first international weather forecasting conference and first joint conference between the AMS and the National Weather Association. He also served as an executive member of the AMS Forecast Improvement Group. He has also served as a member of the National Research Council's Surface Transportation Weather task force the FAA's Turbulence Product Development Team. In 2017, Dr. Neilley was named a Fellow of the American Meteorological Society.

Education

Ph.D. Meteorology, Massachusetts Institute of Technology 1990.Jules Charney Scholarship in Meteorology. Thesis titled "Interactions between synoptic-scale eddies and the large-scale flow during the life cycles of persistent anomalies." Randall M. Dole, advisor.

M.S. Meteorology, Massachusetts Institute of Technology, 1984. *Thesis titled "The vertical structure of the New England coastal front*." Richard E. Passarelli, advisor.

B.S. Meteorology, McGill University, 1982 University Scholar of Great Distinction, American Meteorological Society Undergraduate Scholarship Prize (2nd place).

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Phone 978-983-6554
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M.S. Meteorology, Massachusetts Institute of Technology, 1984. *Thesis titled "The vertical structure of the New England coastal front*." Richard E. Passarelli, advisor.

B.S. Meteorology, McGill University, 1982 University Scholar of Great Distinction, American Meteorological Society Undergraduate Scholarship Prize (2nd place).

Professional experience

2016-, Director, Forecasting Sciences and Technologies and IBM Distinguished Engineer, IBM/The Weather Company. Andover, MA. Responsible for the research, development and operations of weather forecasting and other meteorological technologies emanating from The Weather Company including managing a technical staff of Ph.D. and master's level meteorologists and engineers responsible for creating next-generation weather forecasting capabilities including numerical weather prediction, machine-learning, ensembling, post-processing and large-data deployment technologies.

2009-2015, Senior Vice President, Global Forecasting Services, The Weather Company. (Former title prior to IBM acquisition). Additional duties included responsibility for an operational staff of about 60 meteorologists with offices in Atlanta, Boston, Dallas-Ft. Worth, Chicago, New York and Birmingham U.K. Also provided technical oversight of WSI's EEC Weather Radar division (held until 2012), the WSI regional and lightning detection systems division (USPLN/GLN) WSI's IT and broadcast television production teams.

Prior positions at IBM/The Weather Company/WSI:

> **Vice President, Forecasting Operations, Research and Development**, 2007-2009.
>
> **Director, Forecasting Research and Development**, 2001-2006.

1998-2000, Project Scientist II, National Center for Atmospheric Research (NCAR), Boulder CO. Member of the scientific staff at NCAR Research Application Laboratory and participated in a wide range of research and prototyping initiatives, mostly in aviation weather and hazards detection. This included principal scientist for a number of projects to understand, predict, develop and deploy systems to warn of terrain-induced and convective weather hazards in the vicinity of the new Hong Kong Airport and similar FAA-sponsored programs in Juneau AK and Colorado Springs CO. Developed numerous automated detection and forecasting methods and was a principal inventor and architect of the DICast automated weather forecast engine. Participated in the design and execution of several large programs for the measurement of various atmospheric conditions and hazards and logged hundreds of hours on board various aviation weather research flights.

Prior positions at NCAR:

Associate Scientist III, 1994-1998
Visiting Scientist, 1991-1993

Select Committees and Community Service

EPIC Summer Community Workshop program committee, 2019.

Co-Chair, UCAR Community Advisory Committee for NCEP (UCACN). 2016- (Regular committee since 2015), with Gary Lackman, North Carolina State University.

UCACN Model Advisory Committee (UMAC). NOAA/NCEP model review board, 2015-.

AMS Curriculum Statement Writing Committee, 2016.

AMS Forecast Improvement Group Executive Committee. 2013-

NOAA, Science Advisory Board Environmental Information Services Working Group (EISWG). 2009-2015.

NOAA, Earth Systems Research Lab Global Sciences Division Review Board, 2015.

National Center for Atmospheric Research, Observing Facilities Assessment Panel (OFAP), 2012-2015.

Chair, AMS Weather Analysis and Forecasting Committee. 2008-2012. (Regular committee member 2005-2008).

AMS Board on Data Stewardship 2012-2015

AMS, Committee on Open Environmental Information Services, 2014-

University of Massachusetts-Lowell, Advisory Board on Geosciences, 2011-2015

National Research Council, Transportation Research Board Task Force on Surface Transportation Weather 2003-2011

AMS, Board of Enterprise Meteorology, 2006-2009.

Plymouth State University Task Force on Graduate Studies in Meteorology. 2004-2005.

Federal Aviation Administration, Aviation Weather Research Group, Turbulence Product Development Team, 1997-2001.

Various doctoral and master's thesis committees.

Certifications and Awards

Fellow of the American Meteorological Society

IBM Distinguished Engineer

Holds 14 patents and 1 pending patent application.

National Center for Atmospheric Research, Scientific and Technical Achievement (2nd place) for “Development of a Dynamic, Integrated Forecast System”.

Private pilot license (single engine land)

Selected Publications and Conference Presentations

Neilley, P.P. and T.A.Hutchinson, 2019: The Operational Implementation of MPAS for Global, Convective-Allowing, Rapid-Update NWP on a GPU-Enabled HPC. Meteorological Technology World Expo, Geneva.

Neilley, P.P. and J. K. Williams, 2018: When Good Weather Isn’t Good Enough: The Operations to Decisions Divide. 13th Symposium on Societal Applications: Policy, Research and Practice. American Meteorological Society Conference.

Neilley, P.P., 2018: A Few Frontiers in AI for Applied Meteorology. Invited keynote at the 2018 IEEE Science Conference, Amsterdam.

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Neilley, P. P., and B. Rose, J. Koval, T. Hutchinson, P. Bayer, J. McDonald, J Mathews, W. Cassanova, D. Eck, N. McGillis, S. Tanner and E.r Floehr, 2015: Overview of The Weather Company’s Principal Forecasting Methodologies. 27th Conference on Weather Analysis and Forecasting, Chicago, IL.

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Williams, J. K., and P. P. Neilley, J. Koval and J. McDonald, 2016: Consensus Forecasting using Constrained Regularized Forecasting., 23rd Conf. on Prob and Stat., New Orleans, LA.

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Neilley, P. P., W. Myers and G.S. Young, 2002: Ensemble, Dynamic MOS. Proceedings of the 16th Conference on Probability and Statistics in the Atmospheric Sciences. American Meteorological Society, Boston , MA.

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