

TESTIMONY

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Restoring U.S. Leadership on Weather Forecasting, Part 2

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Chairman Stewart, Ranking Member Bonamici, and other Members of the Committee, thank you for the opportunity to speak with you today on the need for improving weather forecasting for the Nation. My name is Shuyi Chen and I am a Professor at the Rosenstiel School of Marine and Atmospheric Science of the University of Miami. I am a member of the Board on Atmospheric Sciences and Climate (BASC) of the National Academy of Sciences. I am a Fellow of the American Meteorology Society. It is an honor for me to testify on Restoring U.S. Leadership on Weather Forecasting.

My research and professional service have centered on understanding and improving prediction of tropical weather systems, especially hurricanes. I served as an Editor for *Weather and Forecasting* of the American Meteorological Society. I am currently a member of the Science Advisory Board for the Development Testbed Center (DTC). I also serve on the Advisory Board for the Weather Research and Forecast (WRF) model community. I was on the National Research Council's (NRC) Committee on Progress and Priorities of U.S. Weather Research and Research-to-Operations Activities, which produced the NRC report (2010) "*When Weather Matters – Science and Services to Meet Critical Societal Needs.*" Most recently I was appointed by the National Academy of Sciences Division on Earth and Life Science to oversee the review of the NRC Report (2012) "*Weather Services for the Nation – Becoming Second to None.*"

I have devoted more than 20 years conducting research to further understanding of weather systems and improve weather prediction through observations and numerical modeling. My research group at the University of Miami has developed a next-generation high-resolution coupled atmosphere-wave-ocean model to better understand and predict hurricane structure and intensity. I was a principal investigator for three major hurricane/tropical cyclone research programs. One is the National Science Foundation supported Hurricane Rainbands and Intensity Change Experiment (RAINEX), which used three Doppler radar aircraft and collected unprecedented in-situ data in Hurricanes Katrina, Rita, and Ophelia during the 2005 Hurricane Season. The other two are the Coupled Boundary Layer Air-Sea Transfer (CBLAST)-Hurricane in 2003-04 and the Impact of Typhoons on the Ocean in Pacific (ITOP) in 2010 sponsored by the Office of Naval Research, which aimed to better understand the role of air-sea interaction in

hurricane structure and intensity change. These research results have been published in *Science*¹, *BAMS*², and *JAS*³ among others. Currently I am a lead scientist of the National Oceanography Partnership Program (NOPP) model development team to build a new, high-resolution, fully coupled atmosphere-wave-ocean model with a unified air-sea interface that is designed with inter-operability to facilitate research to operations. This new modeling approach is current under testing in the U.S. Navy atmosphere-ocean prediction modeling system.

As we all know, accurate weather forecasts and warnings can save lives and help prevent natural hazards from becoming disasters. Improving weather forecasts and warnings must be a national priority. Over the last two decades, weather research in U.S. has made tremendous progress in better understanding weather processes and in advancing our ability to observe and predict weather. Atmospheric scientists of the United States are among the best in the world. Our weather research capability is admired by all other nations. The United States led the field of numerical weather prediction (NWP) since its inception in the 50's and 60's. However, we are no longer the leader of the field and our operational weather prediction skill fell behind those of some other nations as found by three recent NRC reports (2010a⁴; 2010b⁵; 2012⁶). I believe we can fully materialize our potential in numerical weather prediction and our weather forecasts can be the best in the world. But first we need to identify our weaknesses and the challenges we are facing, otherwise we cannot find solutions to them and we will not make progress. I commend the Committee for taking the leadership to address this important issue of restoring U.S. leadership in weather forecasting.

In this context, I will focus in my testimony on three themes:

- A holistic approach to transition from research to operations;
- Integrated quantitative assessment and planning for new observing systems; and
- Weather forecasting beyond two weeks.

1. A Holistic Approach to Transition from Research to Operations

U.S. weather research has been on the leading edge in terms of innovation and breath in basic research that has led to improvement in weather forecasting, especially in the area of high-impact weather forecasting and warnings in NOAA. This is clearly evident during the recent severe weather events in Moore, Oklahoma and the Superstorm Sandy along the east coast seaboard. Basic research has played a vital role in advancing weather research and forecasting in the U.S.

¹ Houze, R.A., S.S. Chen, B. Smull, W.C. Lee, M. Bell, 2007: Hurricane intensity and eyewall replacement. *Science*, **315**, 1235-1239.

² Chen, S.S., J.F. Price, W. Zhao, M.A. Donelan, and E.J. Walsh, 2007: The CBLAST-Hurricane Program and the next-generation fully coupled atmosphere-wave-ocean models for hurricane research and prediction. *Bull. Amer. Meteor. Soc.*, **88**, 311-317.

³ Chen, S.S., W. Zhao, M.A. Donelan, and H.L. Tolman, 2013: Directional Wind-Wave Coupling in Fully Coupled Atmosphere-Wave-Ocean Models: Results from CBLAST-Hurricane. *J. Atmos. Sci.*, **70**, doi: <http://dx.doi.org/10.1175/JAS-D-12-0157.1>.

⁴ NRC, 2010a: *When Weather Matters – Science and Services to Meet Critical Societal Needs*. National Academy Press, Washington, DC.

⁵ NRC, 2010b: *Assessment of Intraseasonal to Interannual Climate Prediction and Predictability*. National Academy Press, Washington, DC.

⁶ NRC, 2012a: *Weather Services for the Nation – Becoming Second to None*. National Academy Press, Washington, DC.

and worldwide. Much of the advancement today would have not been possible without a broadly based research from the academic, government, and private research community funded by the National Science Foundation, the Office of Naval Research of DOD, DOE, NASA, NOAA, and others over the last several decades. However, the fruits of the weather research have not been fully harvested by the operations in NOAA. This issue has been the focus of several NRC studies and reports. Many have reached similar conclusions as those found in “*From Research to Operations in Weather Satellites and Numerical Weather Prediction: Crossing the Valley of Death*” (NRC 2000⁷) – a lack of a national strategy and leadership. A similar view was expressed in a provocative article entitled “*The Uncoordinated Giant: Why U.S. Weather Research and Prediction Are Not Achieving Their Potential*” by Mass (2006)⁸. Despite an awareness of the problem and recommendations from many entities, there has been little progress in improving the transition of research to operations, especially in terms of NWP models.

Within NOAA, the National Center for Environmental Prediction (NCEP)/National Weather Service (NWS) has been developing its own NWP models for operations, while the Office of Oceanic and Atmospheric Research (OAR) laboratories have developed separate NWP models. With limited resources NCEP is unable to replace its aging modeling system such as GFS and is unwilling to support extramural research and model development (UCAR, 2010⁹), which leads to intellectual isolation. This vicious cycle continues today. At the same time, the research community outside of NOAA continues to develop a number of next-generation high-resolution NWP models. Unfortunately, there is no pathway for these models to become operational at NCEP.

I applaud the efforts of the Committee for taking the initiative to address this pressing issue in the proposed *Weather Forecasting Improvement Act 2013* [e.g., Section 3 (b)-(3)]. I would urge you to go further.

To develop a national strategy and a systematic approach to transition of start-of-the-art weather research into operations, NOAA cannot do it alone. It needs to “***Engage the entire (weather) enterprise to develop and implement a national strategy for a systematic approach to research to operations and operations to research.***” – A key recommendation by NRC (2012).

Recent development of the Rapid Refresh (RAP) model and data assimilation system and the High-Resolution Rapid Refresh (HRRR) hourly updated model is perhaps the best example of a community effort linking both the research and operational communities toward NCEP model implementations to replace an aging NWP system known as Rapid Update Cycle (RUC) model for short-range forecasts, especially for the aviation community. The RAP and HRRR both use a version of the Weather Research and Forecast (WRF) model developed at the Center for Atmospheric Research (NCAR), which has more than 7,000 users from a broad research community both in the U.S. and worldwide. Scientists and forecasters at the Global System Division (GSD)/OAR and NCEP worked closely with NCAR on the development of WRF for

⁷ NRC, 2000: *From Research to Operations in Weather Satellites and Numerical Weather Prediction: Crossing the Valley of Death*. National Academy Press, Washington, DC.

⁸ Mass, C., 2006: *The Uncoordinated Giant: Why U.S. Weather Research and Prediction Are Not Achieving Their Potential*. *Bull. Amer. Meteor. Soc.*, **87**, 573–584.

⁹ UCAR, 2010: *2009 community review of the NCEP Office of the Director*. Boulder, CO.

operations. The RAP and HRRR have also benefited from using a community data assimilation system, the Gridpoint Statistical Interpolation (GSI) system. GSD has also worked closely with NCEP, NASA, NCAR, and the Air Force Weather Agency (AFWA) on development of GSI, including enhancements (e.g., radar, cloud, near-surface data assimilation) specifically needed for RAP and HRRR, which is now available to the GSI community. Recent improvement on forecasts of convective weather systems using RAP and HRRR shows the benefit from the broad collaboration at a grass root level.

However, without a national strategy, a systematic approach, and a viable infrastructure to facilitate a smooth transition from research to operations, the goodwill from individuals alone cannot meet the ultimate challenge of research-to-operations at the national level.

To restore U.S. leadership in weather forecasting, we need a new, transformative, integrated system to transfer state-of-the-art weather research to operations. This system should be overseen by a group/organization of experts from research, operations, and user community of the weather enterprise and should be capable of:

- Developing a community-based NWP modeling and data assimilation system that is flexible using a community-standard source code to incorporate innovations in weather research and technology (e.g., the next-generation, unified global non-hydrostatic, fully coupled atmosphere-wave-ocean-land model and data assimilation system);
- Rapidly transferring research products and new technologies to NOAA and other operations (including private sectors);
- Providing accurate weather forecasts and emerging needs for impact forecasts (e.g., tornado outbreaks, hurricane-related storm surges, flash floods and power outage) and warnings on the short lead time of days to hours, and potential risk for drought, floods, wild fires, hurricane genesis and track on extended lead time of weeks.

The next-generation community-based system(s) should also have the capability of providing user-driven impact forecasts, which has been one of the key recommendations in the NRC “*When Weather Matters*” report (NRC, 2010a). It will be more transparent and efficient for:

- Communicating with federal and local government to optimize the utility of the forecast and assessment products in public response;
- Training the next-generation of scientists and forecasters with innovative tools for prediction and impact mitigation;
- Educating vulnerable residents on the application value of the new information coming out of the integrated forecast system on short and long lead times.

2. Integrated Model-Data Assimilation for Observing System Assessment and Planning

Another key in improving weather forecasting is the capabilities of observing states of the atmosphere, land, and ocean, which is absolutely essential to our understanding and new discovery of nature and to meet the need for numerical weather prediction and data assimilation. It is critical for us to understand the impact of current observing systems on weather prediction as well as anticipate future observing system needs and requirements. We must put in place an

advanced, systematic, assessment and evaluation system for current and new observing systems. The traditional approach has been using observing system experiments (OSEs) to assess impacts of existing observations on numerical model prediction, and observing system simulation experiments (OSSEs) for future observations. However, OSSEs are rarely used because of its large uncertainty due to model biases and a lack of independence between the model simulated “nature” state and its data assimilation system.

Because the shortcomings of OSSEs, some operational centers including the U.S. Navy, NASA, and the European Center for Medium-Range Weather Forecasts (ECMWF) have chosen to develop new alternative approaches using adjoint and/or ensemble data assimilation (EDA) system for observing system assessment and planning. New and better technologies are likely continue to be developed in the future (NRC, 2012). For these reasons, I would urge caution for legislate specific technologies for observing system assessment and planning (re. Section 7 in the proposed *Weather Forecasting Improvement Act 2013*), but will be best to encourage innovations and new technology development.

3. Weather Forecasts Beyond Two Weeks: A New Frontier

Focusing on the near-term improvement of weather forecasts and warnings, especially high impact weather such as tornadoes and hurricanes, is important. But we must also recognize that the need and economic values of extending weather forecasts beyond one week, known as extended weather forecasts on subseasonal time scale (1–4 weeks). Recent research has found that the occurrence probabilities of tornados and hurricanes significantly fluctuate on that time scale. Other phenomena also fluctuating on that time scale include drought, flooding and heat waves, all having great impacts on society. A better understanding and improvement of subseasonal forecasts are needed to bridge weather and seasonal forecasts at the weather and climate interface, which has been documented in the World Weather Research Program (WWRP) Implementation Plan¹⁰ and the NRC report (2010b).

From the end-user perspective, extended weather forecasts are very important, because many management decisions, such as in agriculture and preparation for high impact weather (flood, heat waves, hurricanes, wild fires) and proactive disaster mitigation, fall into this scale. Reliable and skillful subseasonal forecasts for this timescale would be of considerable value.

Recent research has indicated important potential sources of predictability for this time range such as slowing evolution in tropical convection, stratospheric influences, and land/ice/snow interactions. Recent improvements in computing resources and model development may make it possible to develop a better representation of these sources of extended weather predictability. Several operational centers are now producing operational subseasonal forecasts.

In principle, advanced notification, on the order of two to several weeks, of the probabilities of hurricanes, tornados, severe cold outbreaks and heat waves, torrential rains, and other potentially high impact events, could help protect life and property; humanitarian planning and response to disasters; agriculture and disease planning/control (e.g., malaria and meningitis); river-flow and

¹⁰ WWRP, 2013: *Subseasonal to Seasonal Prediction*. Research Implementation Plan. WMO.

river-discharge for flood prediction, hydroelectric power generation and reservoir management; landslides; coastal inundation; transport; power generation; insurance. There are tremendous potential benefits from reliable extended weather forecasts to reductions in mortality and morbidity and to economic efficiencies across a broad range of sectors.

In recent years, operational forecasting systems dedicated to subseasonal prediction have been implemented in many NWP centers (including NCEP and ECMWF). Demands for such forecast have been increasing. Types of subseasonal forecast products are, however, still limited. Errors and uncertainties of subseasonal forecasts are still large. With focused research-operation integration, substantial improvement of subseasonal forecast skill and elevated societal benefit are within our grasp.

The weather enterprise has entered a new era of extended weather forecasts beyond two weeks. Science and technology advancements have made it not only possible but also practical to made substantial improvement in extended weather forecasts. What we need is a determination and well thought of plan. A consortium of academic, government, and private sectors within the weather enterprise is recommended to lead the Nation's effort to make measureable advancement in extended weather forecasts to meet the society's need and to be the best in the world.

4. Conclusion

To restore U.S. leadership in weather forecasting should be a national priority. NOAA cannot do it alone. It will take the entire weather enterprise. Congress can help. You must.

There is no doubt that improving the weather forecasts and response to save lives and reduce economic loss should be a national priority. The rapid advancement of science and technology presents us with an unprecedented capability and opportunity to develop the integrated weather forecast and response system that will support risk assessments and emergency management by reducing warning areas and providing forecasts with longer lead time. There is critical need for the involvement of the NSF to support the ambitious and risky interdisciplinary research agenda, in ways that go beyond what is feasible in individual mission-oriented government agencies. The development and operation of such an integrated weather forecast and response system requires collaboration and coordination among many research disciplines and among the research community and government and impacted sectors. Further, successful implementation of such a system requires the education of a new generation of scientists, technicians, forecasters, government managers, and will guarantee a smooth transition from research to NOAA operations.