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PRIVATE SECTOR WEATHER FORECASTING: ASSESSING PRODUCTS AND TECHNOLOGIES

HEARING

BEFORE THE

SUBCOMMITTEE ON ENVIRONMENT

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTEENTH CONGRESS

SECOND SESSION

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June 8, 2016

PRIVATE SECTOR WEATHER FORECASTING: ASSESSING PRODUCTS AND TECHNOLOGIES

WEDNESDAY, JUNE 8, 2016

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENVIRONMENT AND
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 9:32 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Jim Bridenstine [Chairman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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Subcommittee on Environment

Private Sector Weather Forecasting: Assessing Products and Technologies

Wednesday, June 8, 2016
9:30 a.m. – 11:00 a.m.
2318 Rayburn House Office Building

Witnesses

Mr. Barry Myers, CEO, AccuWeather

Mr. Jim Block, Chief Meteorological Officer, Schneider Electric

Dr. Neil Jacobs, Chief Scientist, Panasonic Weather Solutions, Panasonic

Dr. Antonio Busalacchi, Director, Earth System Interdisciplinary Center, University of Maryland

Dr. Sandy MacDonald, Director, Numerical Weather Prediction, Spire Global

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HEARING CHARTER

Wednesday, June 8, 2016

TO: Members, Committee on Science, Space, and Technology

FROM: Majority Staff, Committee on Science, Space, and Technology

SUBJECT: Environment Subcommittee hearing "Private Sector Weather Forecasting: Assessing Products and Technologies"

The Subcommittee on Environment will hold a hearing titled *Private Sector Weather Forecasting: Assessing Products and Technologies* on Wednesday, June 8, 2016, at 9:30 a.m. in Room 2318 of the Rayburn House Office Building.

Hearing Purpose:

The purpose of the hearing is to examine the weather forecasting products and technologies of the private sector.

Witness List

- **Mr. Barry Myers**, CEO, AccuWeather
- **Mr. Jim Block**, Chief Meteorological Officer, Schneider Electric
- **Dr. Neil Jacobs**, Chief Scientist, Panasonic Weather Solutions, Panasonic
- **Dr. Antonio Busalacchi,** Director, Earth System Interdisciplinary Center, University of Maryland
- **Dr. Sandy MacDonald**, Director, Numerical Weather Prediction, Spire Global

Staff Contact

For questions related to the hearing, please contact Majority Staff at 202-225-6371.

Chairman BRIDENSTINE. The Subcommittee on Environment will come to order.

Without objection, the Chair is authorized to declare recesses of the Committee at any time.

Welcome to today's hearing titled "Private Sector Weather Forecasting: Assessing Products and Technologies." I recognize myself for five minutes for an opening statement.

Good morning, and welcome to this morning's Environment Subcommittee hearing.

The American weather enterprise is made up of stakeholders that provide services which ultimately save lives and property. Among these are private-sector weather forecasting companies that over the years have become a major source of weather information. Today we have companies that specialize in sector-specific forecasting, as well as companies which create their own forecasts that are disseminated to millions of Americans.

The services they provide are essential to protecting Americans in the face of severe weather. This is particularly important to me as my constituents in Oklahoma face some of the most severe weather in the country. Providing them advanced warnings is critical. I look forward to hearing about the advances made by private-sector weather companies working on the forefront to protect lives and property.

NOAA currently provides important data which is then utilized by other stakeholders to construct forecasts. Many private-sector companies also use their own methods and technologies to enhance this data.

To me, there is a clear delineation here. NOAA should focus on providing the foundational datasets that others utilize to produce life-saving forecasts, rather than duplicating efforts and technologies that are employed or could be employed by the private sector.

As an example, the main tenet of H.R. 1561, the Lucas-Bridenstine Weather Research and Forecasting Innovation Act, is its recognition of the role commercial weather data can play as a piece of the solutions available to NOAA. In the face of looming data gaps, we need to maintain continuous, efficient, robust, and cost-effective data streams to feed the initial conditions of our numerical weather prediction models.

This Subcommittee has a long history of oversight of NOAA's satellite programs, which over the years have been plagued with cost-overruns, delays, and mismanagement. This has underscored my belief that we need to augment our space-based observing systems by incorporating alternative methods of data collection.

Earlier this year before this subcommittee, NOAA Administrator Kathy Sullivan testified to the ability of the private sector to produce weather data. She testified that "In the weather domain, we believe it is a promising but still quite nascent prospect to actually have data flows from private-sector satellites." Today, I am pleased to have one of the many private-sector satellite companies before us to discuss their perspectives on commercial weather data.

I was encouraged by NOAA's budget request this year for commercial weather, which includes funding to continue the Commercial Weather Data Pilot program authorized by our House-passed

weather bill. This pilot program is an important signal to the private sector that NOAA is interested in new and innovative sources of data.

Likewise, I was also encouraged to see NOAA incorporate a line item for the purchase of radio occultation data as a potential alternative to another constellation of COSMIC satellites.

The Commerce, Justice, and Science Appropriations bill supports both these initiatives, and I'd like to thank my colleagues on that committee, particularly Chairman Culberson.

In light of these directions from Congress, I look forward to following up with NOAA to find out how these decisions will be made.

I look forward to an in-depth discussion today about how private-sector data and products can build on the foundation provided by NOAA to help enhance the safety of all Americans.

[The prepared statement of Mr. Bridenstine follows:]

COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
Lamar Smith, Chairman

For Immediate Release
June 8, 2016

Media Contacts: Alicia Criscuolo, Thea McDonald
(202) 225-6371

Statement of Environment Subcommittee Chairman Jim Bridenstine (R-Okla.)
Private Sector Weather Forecasting: Assessing Products and Technologies

Chairman Bridenstine: Good morning and welcome to this morning's Environment Subcommittee hearing entitled "*Private Sector Weather Forecasting: Assessing Products and Technologies.*" I'd like to first thank our witnesses for being here today.

The American weather enterprise is made up of stakeholders that provide services which ultimately save lives and property. Among these are private sector weather forecasting companies that over the years have become a major source of weather information. Today we have companies that specialize in sector specific forecasting, as well as companies which create their own forecasts that are disseminated to millions of Americans.

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I look forward to an in depth discussion today about how private sector data and products can build on the foundation provided by NOAA to help enhance the safety of Americans. I now recognize the gentlewoman from Oregon, the ranking member, Ms. Bonamici for an opening statement.

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Chairman BRIDENSTINE. I now recognize the gentlewoman from Oregon, the Ranking Member, Ms. Bonamici, for an opening statement.

Ms. BONAMICI. Thank you very much, Mr. Chairman, and thank you to all of our witnesses for being here today.

I'd like to start by congratulating Dr. Busalacchi, who will soon be the President of the University Corporation for Atmospheric Research later this summer.

Today's hearing is an opportunity to hear about the successes of the private weather industry, learn about the impressive weather research being conducted at academic institutions, and recognize the critical role that the National Weather Service has played, and will continue to play, in ensuring the strength and continuity of the entire American weather enterprise.

The three sectors that make up the weather enterprise—private, public, and academic—work collectively to meet the needs of the public, inspire growth and innovation, and protect life and property. To maintain the progress we have made over the last decade, we must explore opportunities to leverage expertise across these sectors. More can be done by NOAA and the Weather Service to strengthen this partnership and keep us on a path of serving the public even better.

If, however, Congress were to reduce the role of one sector, or shift responsibilities without considering how such a change might affect the entire enterprise, we risk upsetting the balance and losing the progress so many of us have worked so hard to achieve.

In 2003, the National Academies released their seminal report on the weather partnership, "Fair Weather: Effective Partnerships in Weather and Climate Services", and their recommendations state that continued success requires recognizing the core mission of each partner.

The core mission of the National Weather Service is to provide weather forecasts and warnings to protect life and property, and to enhance our national economy. The NWS network includes thousands of forecasters, across hundreds of forecast offices, who support the critical infrastructure of observing, data processing, prediction, and dissemination systems. Research taking place at our academic institutions advances the science needed to make forecasts more accurate, while inspiring the next generation of meteorologists. The private sector has the ability to use both the research and NWS data to tailor exciting new products to meet the changing demands of a diverse set of end-users and consumers.

Although some advocate for disaggregating the current structure, I am confident that the weather enterprise is stronger together. In the 13 years since the release of the Fair Weather Report, the weather partnership has flourished and the state of U.S. weather forecasting is strong. Although we should always look for ways to improve, we must do so in ways that strengthen each partner, not diminish any of the key roles.

I look forward to the discussion today about how we can accomplish that goal.

Thank you, Mr. Chairman, for your leadership on this issue, and I yield back the balance of my time.

[The prepared statement of Ms. Bonamici follows:]

OPENING STATEMENT
Ranking Member Suzanne Bonamici (D-OR)
Of the Subcommittee on Environment

House Committee on Science, Space, & Technology
Subcommittee on Environment
"Private Sector Weather Forecasting: Assessing Products and Technologies"
June 8, 2016

Thank you Mr. Chairman, and thank you to all of our witnesses for being here today.

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Mr. Chairman, I yield back the balance of my time.

Chairman BRIDENSTINE. I'd like to thank the Ranking Member, and I now recognize the Ranking Member of the full Committee, Ms. Johnson, for an opening statement.

Mrs. JOHNSON OF TEXAS. Thank you very much, Mr. Chairman, and good morning, all.

People in Texas are very familiar with the impact weather has on our daily lives. As a matter of fact, there is a common saying that we have all four seasons, and some days we have all of them in one day. In just the last few weeks, terrible floods have taken the lives of more than a dozen people.

Weather has a universal impact, and it is only through reliable and accurate forecasts that we are able to act to protect ourselves. This is why the mission of the National Weather Service is to provide weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy. So while this hearing is part of an ongoing dialogue regarding the role of the commercial weather industry in our weather enterprise, we must keep in mind that the protection of our citizens and national security are inherently government functions.

That is why, in 2003, the National Academies Fair Weather Report provided recommendations of how to strengthen the existing partnership between the Weather Service, academia, and the private sector, and not simply strip away government functions as some may suggest. Despite the claims by some that we must disaggregate the weather enterprise, it is very clear to me that the existing partnership between these three sectors has made our weather forecasts more reliable and more accurate.

We will hear from some of the witnesses that NWS should focus on its core functions and let private companies handle the rest. However, if weather data collection and weather forecasting are not core functions of the NWS, I don't know what is. As we must work to ensure that NWS's forecasts are as accurate and timely as possible, we need to make sure that NWS has the resources and mandates to do so.

It should also be noted that NWS weather data has enabled the growth of a significant value-added industry. There may be ways that the private sector can complement and support that mission, but I'm very skeptical that transferring all of the responsibilities to the private sector is either wise or necessary, and therefore I do not support doing so.

And finally, I would have hoped the Majority would have invited NOAA and the Weather Service to participate in this hearing but I look forward to hearing their perspective at another time.

I thank you, Mr. Chairman, for having the hearing, and I yield back the balance of my time.

[The prepared statement of Mrs. Johnson of Texas follows:]

OPENING STATEMENT
Ranking Member Eddie Bernice Johnson (D-TX)

Committee on Science, Space, & Technology
Subcommittee on Environment
"Private Sector Weather Forecasting: Assessing Products and Technologies"
June 8, 2016

People in Texas are very familiar with the impact weather has on our daily lives. In just the last few weeks, terrible floods have taken the lives of more than a dozen people. Weather has a universal impact and it is only through reliable and accurate forecasts that we are able to act to protect ourselves. That is why the mission of the National Weather Service is to "provide weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy." So while this hearing is part of an ongoing dialogue regarding the role of the commercial weather industry in our weather enterprise, we must keep in mind that the protection of our citizens and national security are inherently government functions.

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We will hear from some of the witnesses that NWS should focus on its "core" functions, and let private companies handle the rest. However, if weather data collection and weather forecasting are not "core" functions of the NWS, I don't know what is. As we must work to ensure that NWS's forecasts are as accurate and timely as possible, we need to make sure that NWS has the resources and mandate to do so.

It should be noted that NWS weather data has enabled the growth of a significant "value-added" industry. There may be ways that the private sector can complement and support NWS's mission, but I am very skeptical that transferring NWS's responsibilities to the private sector is either wise or necessary, and I do not support doing so.

Finally, I would have hoped the Majority would have invited NOAA and the Weather Service to participate at this hearing. I look forward to hearing their perspective at another time.

Chairman BRIDENSTINE. The gentlelady yields back.

Let me introduce our witnesses, and because we're short on time—we have the Prime Minister from India here today—I'm going to skip the long and impressive bios, and I'll just introduce the individuals here.

Our first witness today is Mr. Barry Myers, CEO of AccuWeather. Our next witness today is Mr. Jim Block, Chief Meteorological Officer for Schneider Electric. Our third witness today is Dr. Neil Jacobs, Chief Scientist for Panasonic Weather Solutions. Our next witness is Dr. Antonio Busalacchi, Director of the Earth System Interdisciplinary Center, and Professor in the Department of Atmospheric and Oceanic Science at the University of Maryland. And our final witness today is Dr. Sandy MacDonald, Director of Numerical Weather Prediction at Spire Global.

So I will now recognize Mr. Myers for five minutes—we'll say three minutes—to present his opening testimony.

TESTIMONY OF MR. BARRY MYERS, CEO, ACCUWEATHER

Mr. MYERS. Good morning, Chairman Bridenstine, Ranking Member Bonamici, and members of the Subcommittee.

AccuWeather is a global leader in weather information and digital distribution, and I'm honored to be invited to participate in today's hearing.

The United States has the best weather information available to its citizens and its business and industrial sectors of any Nation. This result did not occur by the American weather industry acting alone; it was and continues to be the interactive, cooperative approach of the weather industry, the academic research community, and NOAA and its National Weather Service that has led to this result. These entities form the Nation's weather enterprise.

American weather companies are now becoming the focal point for weather information in many countries around the world. For example, the number one weather mobile source in Europe is an American company, AccuWeather. We estimate that AccuWeather information is on 1.5 billion or more devices globally. It's American business leadership, academic research, and government partnerships that are propelling this American weather phenomenon.

Some believe that the reduction in weather-related deaths in the United States since the late 1950s when the American weather industry was at its beginning through the joint and collaborative efforts within the weather enterprise have saved as many as 1 to 2 million lives. These successes were enabled by the foundational partnership between the National Weather Service and the weather companies that directly receive NWS data, observations, forecast models and so forth, which the weather companies and private-sector meteorologists develop into weather information products for Americans and for the global marketplace. Private-sector innovation and investment has enabled many of the technological advances in how American weather companies communicate weather to the public.

At the end of World War II, about 98 percent of the weather information received by the public came from the government directly, and now it's estimated that that's reversed and about 98

percent comes from the weather industry, and this includes special warnings for tornadoes, hurricanes, floods, et cetera. The 24/7/365 acquisition and distribution of core foundational data, funding research and development, and running of models and issuing government warnings are some of the most important things that the National Weather Services does, and those that the entire weather community and the public rely on.

There needs to be a renewed effort within the weather enterprise with the Environment Subcommittee through its oversight role to strengthen the foundational data partnership between the National Weather Service and the private-sector weather industry, which industry is now woven into the fabric of American life. America's weather industry is a critical piece of the Nation's weather value chain as the 2012 National Academy of Sciences report clearly points out. The private weather sector needs to be supported and nurtured by NOAA for the good of the Nation.

If NOAA does its part, the private sector will do its part by continuing to foster technological innovation in the development of more advanced and sophisticated weather products, forecast services, presentations, and communication of weather and warnings to the public.

Mr. Chairman and members of the Subcommittee, thank you for inviting me to participate today. I would be pleased of course to answer any questions you may have.

[The prepared statement of Mr. Myers follows:]

Statement of
Mr. Barry Lee Myers, CEO, AccuWeather, Inc.

Before the

Subcommittee on Environment
Science, Space, and Technology Committee
U.S. House of Representatives

Hearing on

"Private Sector Weather Forecasting:
Assessing Products and Technologies"

June 8, 2016

Good morning, Chairman Bridenstine, Ranking Member Bonamici, and Members of the Subcommittee. My name is Barry Myers and I am the CEO of AccuWeather, Inc. headquartered in State College, PA. and has U.S. offices in Kansas, Oklahoma, New York. I am honored to be invited to participate in today's hearing to examine the advancement and progress that has been made by the private sector in weather forecasting.

The United States of America has the best weather information available to its citizens, and its business and industrial sectors, of anywhere on Earth.

Some believe that the reduction in weather-related deaths in the United States since the late 1950s, when the American Weather Industry was at its beginning, through the joint work of the weather industry, the academic research community, and the government weather services – that perhaps as many as one to two million American lives have been saved.

It is the foundation of "free and open" access to information that has brought about the environment that fostered the world's most robust weather industry.

It is built on the concept that if information the government had is freely available in real time, all the rest can be left to innovative

entrepreneurs, who would find ways to make a viable industry and serve the public.

This has allowed transition from a government agency "doing it all," at the end of World War II, to massive infusion of weather into every American's life through companies like AccuWeather, The Weather Channel, WeatherBug, and others - and a growing global presence by American companies, as the preferred suppliers of weather to the world.

In fact, a tax-paying industry - creating probably tens of thousands of direct and related jobs - was born. Back then the public relied almost 100% on weather forecasts from the government and now it is believed 95% of the public get their weather information from the weather industry. A complete reversal.

It has been a transition of work from the government to the private sector involving no government contracts, no industry subsidies, no special data deals, and no cost to the government beyond acquisition of the information for its own needs and the sharing the data and products it has. The weather industry has always paid for the cost to connect to the government information access ports, to transport the information to its own facilities, and to process and analyze it, and build new products and services

on that foundation. This is an investment I would estimate to be in the hundreds of millions of dollars.

How many in this room have a mobile device, phone or tablet on their person, in their briefcase, in their home, and/or at work? How many of your spouses and children have such devices? I would wager that virtually every such device and every computer and smart television has instant access to weather information.

Weather is at every American's fingertips. How it got there and how is it refreshed almost second by second, 24/7, is the success story of the private sector weather industry.

This result did not occur by the American Weather Industry acting alone. It was, and continues to be, the interactive and cooperative approach of the weather industry, the academic research community, NOAA and its National Weather Service, that has led to this result.

American weather companies are now becoming the focal point for weather information in many of the countries around the world. The number one mobile weather source in Europe is an American one - AccuWeather. We estimate that AccuWeather information is on about 1.5 billion or more devices globally.

It is American business leadership, academic research, and government leadership, that are propelling this American weather phenomenon. It is similar to the industry founded on the GPS satellites. The United States government created the satellites, placed them in orbit, maintains the system, and makes it freely accessible to anyone with a GPS receiver. Companies take that capability and make all kinds of products for the public marketplace.

American constitutional principles – and enshrined in such laws as The Paperwork Reduction Act and in guidelines such as OMB Circular A-130 - that the information the U.S. government collects and acquires, and that information that it generates, belongs to the people and should be available free and openly, has created this world leadership and American success story.

It is a foundation of free and open access to the information that leads the world as a model for other nations and the principle that has brought about the environment for the world's most robust weather industry to develop. It is the weather equivalent of the "GPS system" from which the public receives innovative weather information.

One small example can be seen in an event a few years ago when a tornado formed during a February night in Mississippi. In an area outside of

any NWS warning, outside of any siren sounding, a tornado struck a manufacturing facility staffed with 88 people. The plant was totally destroyed.

The dead and dying were not taken to local hospitals. There were no dead and dying.

AccuWeather had warned this facility 22 minutes in advance, and all the staff members were sheltered underground when the tornado hit.

This is not just a tribute to our severe warning systems and capability, but to the foundational data information from the National Weather Service that we knew we understood and could rely on.

This was not an AccuWeather success alone -- it was a joint success of AccuWeather, the academic community, and the National Weather Service. And it is but one examples illustrating that NWS need not do everything to keep American's safe. Others can share the load.

But, we could not do our part of this job, if NWS had not done its part, and had we all not cooperated in how we all do our jobs.

This one example, is multiplied many times every day, and is all based on the open and free data concept.

And the Big Data / Open Data push from the Department of Commerce for opening up all information the government holds, foretells even more promise for our citizens.

These are concepts that have been universally held by all administrations and Congresses in the past over many decades.

Reports like *The Fair Weather Report* from the National Research Council in 2003 and the more recent National Academy of Sciences study from 2012 entitled *Weather Services for the Nation: Becoming Second to None*, also support these concepts and point out the value of the private sector weather industry, its needs, and its contributions.

This success requires honesty of data, transparency of data, and following the scientific method thereby enabling all in the science to have the data, not just output and products, in complete and real time form.

While talking about open and free data on a big data scale, it is becoming more and more apparent that a "contra undercurrent" is at work within NOAA that portends to disrupt the fabric of the nation's weather enterprise that it serves, by violating the concept of free and open data. This needs to be discussed, studied and resolved by the wider scientific and business community – not just by NOAA acting on its own in a one-by-one fashion as each situation arises.

The privatization of data sources – not a bad business trend in itself – poses a danger when government agrees to licensing provisions that keep data, and even output, captive within the government and yet incorporated into weather products and services in ways that – the American Weather Industry, will no longer be able to discern. This is anti-science.

Privatization does not need to mean keeping data secret within the government and not shared with its private sector partners.

There is a difference between privatized data sources and secret data. There is a difference between Privatization and "Secretization."

With privatization of data from private satellite launches, from meso-nets, and other sources coming on line, we need to have government license arrangements that conform to the spirit and intent of the nation's free and open data philosophy.

NOAA having secret data under the guise of restrictive licensing is the wrong path. Licenses are what two or more parties agree for them to be, and the new data sources coming on line want government contracts to support their companies. That is understandable, but the government has the contracting ability to be king-maker and certainly has the ability to get good deals that do not damage the weather success the nation enjoys.

The 24/7/365 distribution of core foundational data is one of the most important things that the National Weather Service does and one that the entire Weather Enterprise relies on the agency to do successfully. For example, if it begins to use secret data in the development of its weather forecast models and flood inundation mapping, it will render one of its main functions to the community moot. America's Weather Industry and the academic research community needs to understand the data that is used to make forecasts, predict floods, scientifically test models, and ensure protection of the public from tornadoes, hurricanes and other hazards.

Business models can be constructed where only some, or the majority of private data, could be reserved for commercial purposes, and the government could buy data along with redistribution rights.

Too many people are talking about this as getting data from private sources or not getting data from private sources. That is talking in absolutes of "Yes" or "No," not logical business arrangements to achieve necessary outcomes for the nation.

It is bucking up against the need to get to all the data and information that NWS has. And it runs the risk of undermining the very scientific basis that is the core of the agency.

Not having all the data available in real time, in the weather field, is the antithesis of good science.

"Secretization" is not good science, neither is it good for the economy.

If the NWS is just at its core, a mixture of publicly accessible data and secret data, it diminishes its own mission and thereby calls itself and its need, into question.

Deals that the NWS makes trying to support budding sources of data or models must do no harm to the best weather information infrastructure any nation has.

We need to develop creative solutions and more cooperative approaches to being more transparent, not less, and ensure we are embracing free and open data in all situations. We must stay true to the core tenets and principles that have empowered the success of the American weather community.

If the core erodes, the agency's existence will be endangered, and that will not serve the nation's needs. It would be like impairing the functioning of the GPS system, and needing to go back to paper maps in your car.

The weather industry is a critical piece of the nation's weather value chain, as the National Academy report points out and it needs to be supported and nurtured by NOAA for the good of the nation.

New data sources and modeling are good, but they are also a result of the National Weather Service not advancing fast enough in these areas – with focus on social science messaging and general public forecasts.

The best public facing forecasts and information comes from the weather industry and the best atmospheric research is in the academic research community. The nation should be proud of that.

The nation should also support the core missions of NOAA and our National Weather Service. We need quality shared data, support for the development of top notch models, and the best severe weather warnings. Core mission focus is needed for success.

Mr. Chairman and Members of the Subcommittee, thank you again for inviting me to participate today. I would be pleased to answer any questions you may have about my remarks.

END.

Barry Lee Myers is the Chief Executive Officer of AccuWeather, Inc., a position he has held since late 2007. AccuWeather is an American iconic brand in weather known around the world.

He previously served as the company's Executive Vice President and General Counsel.

Recognized as an expert in public/private relationships in the weather and weather media industry worldwide, (although not himself a meteorologist), Mr. Myers has served as special advisor to three separate directors of the National Weather Service and is a Fellow of the American Meteorological Society (AMS).

He has been an invited speaker at the World Meteorological Organization (the United Nations body that coordinates international weather information) and at the World Federation of Scientists, on the topics of weather data exchange and public-private sector relationships in the weather field.

Mr. Myers was involved in advocating for language applying to real-time government data in The Paperwork Reduction Act, and worked with the author of OMB Circular A-130 to further support this concept. This portion of the statute serves as confirmation of the American concept of the free and open availability of weather and other government information (agricultural data, health data, census data) and related government analysis.

He currently serves on the Environmental Information Services Working Group (EISWG) for the NOAA Science Advisory Board. Mr. Myers also served on the steering committee of the AMS Commission on the Weather and Climate Enterprise. He serves on the Boards of the Weather Coalition and of the American Weather and Climate Industry Association.

During Mr. Myers' tenure as CEO, AccuWeather has become the leading force in weather on mobile devices on a global basis. AccuWeather is now believed to be the largest mobile weather provider worldwide, being accessible on an estimated 1.5 billion devices and in January became the only private company authorized in China to do business as a weather provider in the digital media space there.

Mr. Myers holds a B.S. in economics and business administration from the Smeal College of Business at Penn State, and M.S. (ABD) in management science and organizational behavior also from the Smeal College of Business and a Juris Doctor from the Boston University School of Law. He is currently still admitted to practice before the courts of the Commonwealth of Pennsylvania and the United States Supreme Court.

Fo almost two decades Mr. Myers served as a tenured Associate Professor on the graduate faculty of the Smeal College of Business and as a faculty member of the Graduate Program in Regional Planning and developed the first of its kind senior level course on Environmental law.

He has testified before Congressional committees numerous times, has delivered hundreds of speeches, and had scores of published articles in refereed and popular journals.

Chairman BRIDENSTINE. Thank you, Mr. Myers.
Mr. Block, you're recognized for three minutes.

**TESTIMONY OF MR. JIM BLOCK,
CHIEF METEOROLOGICAL OFFICER,
SCHNEIDER ELECTRIC**

Mr. BLOCK. Thank you, Chairman Bridenstine, Ranking Member Bonamici. I appreciate the invitation to testify today on the opportunities for public and private partnership to deliver improved weather forecasting services for American taxpayers.

My name is Jim Block, and I'm a Fellow of the American Meteorological Society and a Certified Consulting Meteorologist at Schneider Electric. Schneider Electric a global Fortune 300 company with 170,000 employees worldwide, $30 billion in sales, and operations in more than 100 countries. We have facilities with almost 300 employees in Ms. Bonamici's district, and 360 in Mr. Rohrabacher's, for example. Schneider Electric is a specialist in energy management and automation offering integrated solutions across multiple market segments including buildings, industrial manufacturers, utilities, and data centers.

We maintain the largest commercial business-to-business weather forecasting and consulting organization in the United States, providing accurate weather forecasting for over 15,000 customers all over the world. We utilize more than 80 separate data sources including those from NOAA. We innovate and develop specialized technology to take the NOAA data and add value by fine-tuning it and aligning it to specific customer needs. For example, we predict turbulence and flight hazards for over 250 airlines. We also help determine the amount of chemicals to put on icy roads for over 30 state transportation agencies. We provide the temperature forecasts used by 70 percent of U.S. utilities as well as protect many sports teams from adverse weather.

Currently, commercial weather services like Schneider Electric focus on solutions to solve specific end-user problems. Conversely, NOAA provides general forecasts and warnings for the overall protection of life and property along with services that support those activities. This division of services between the private and public sectors of weather is very efficient and services the American taxpayer very well. However, it requires more cooperation and communication between NOAA and companies like Schneider Electric to work effectively.

Some critics may question the need for a government weather agency at all. However, we strongly disagree. No commercial entity can operate the weather infrastructure that NOAA operates today, but at the same time, the multitude and diversity of end-user projects can only be addressed by companies like ours and others using information from NOAA and other sources.

We offer the following recommendations to drive public-private partnerships and help deliver the best results to communities and taxpayers. First, there should be more, and more effective, cooperation between NOAA and the private sector. We believe that strong cooperation between NOAA and the private sector is necessary and long overdue, and we believe that NOAA should have a regular committee that includes permanent private-sector members.

Second, NOAA should place more emphasis on the use of existing data sets from commercial sources. We believe there is a need to look at the relationship between NOAA and downstream service providers such as Schneider Electric. We believe that NOAA can benefit from our specialized knowledge of weather information end users. For example, Schneider Electric has built and now operates the largest agricultural weather network in the United States, which consists of more than 4,600 weather stations located on farms, where the data is used by farmers to make critical decisions on a daily basis. This is information that could be tremendously useful to NOAA.

Third, NOAA should eliminate decision support services that duplicate those available in the private sector. NOAA should refrain from overextending its scope beyond data sets and severe weather warnings. We believe that the private sector can and should collaborate with NOAA on any downstream user or business services with clear role delineation. Specialized services have a marginal benefit to the public and needlessly tie up taxpayer dollars on offers that are already available in the private sector. Closer cooperation with NOAA could resolve such situations.

We believe that NOAA's mission can be enhanced and be more cost-effective if NOAA works more closely with the private sector, uses data sets such as the ag weather networks, and eliminates duplicative services.

We commend the Committee for considering our recommendations, and thank you for the opportunity to speak today.

[The prepared statement of Mr. Block follows:]

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Schneider Electric North America

Boston, Massachusetts

Testimony of Jim Block, Chief Meteorological Officer, Weather Division,

Schneider Electric

IN SUPPORT OF PUBLIC-PRIVATE PARTNERSHIPS FOR IMPROVED

WEATHER FORECASTING

Before the House Committee on Science, Space, and Technology on June 8, 2016

Summary:

We offer the following recommendations to drive public-private partnerships and help deliver the best results to communities and taxpayers:

- There should be more, *and more effective*, cooperation between NOAA and the private sector.
- NOAA should place more emphasis on the use of existing data sets from commercial sources.
- NOAA should eliminate Decision Support Services that duplicate those available in the private sector.

Chairman Bridenstine, Ranking Member Bonamici, I appreciate the invitation to testify today on the opportunities that commercial weather services are able to deliver to improve weather forecasting and further the goals of NOAA, the National Oceanic and Atmospheric Administration.

My name is Jim Block, and I am a Fellow of the American Meteorological Society, and a Certified Consulting Meteorologist at Schneider Electric.

Schneider Electric is a global Fortune 300 company with 160,000+ employees world-wide, $30 billion in sales, and operations in more than 100 countries. Schneider Electric is a specialist in energy management and automation offering integrated solutions across multiple market segments, including Commercial and Residential Buildings, Industrials & Machine Manufacturers, Utilities & Infrastructure, and Data Centers & Networks. We maintain the largest commercial business-to-business weather forecasting and consulting organization in the United States, providing accurate weather forecasting and auxiliary services to 15,000 customers all over the world. Every year for the last nine years, Schneider Electric has had the highest temperature and precipitation forecast accuracy, as reported by ForecastWatch (see ForecastWatch appendix items).

We rely on more than 80 separate data sources, including NOAA, to build our forecasts. We innovate and develop specialized technology to take the NOAA data and add value by fine-tuning and aligning it to specific customer needs.

Following are a few examples of real solutions we offer our customers today:

Agriculture: We provide the weather information in the DTN and Progressive Farmer services. We recently deployed a network of almost 3,000 weather and soil sensors at farms, to help farmers make better day-to-day crop production decisions (see Ag Weather slide in Appendix). This intelligence could also be useful to NOAA for future tornado prediction models.

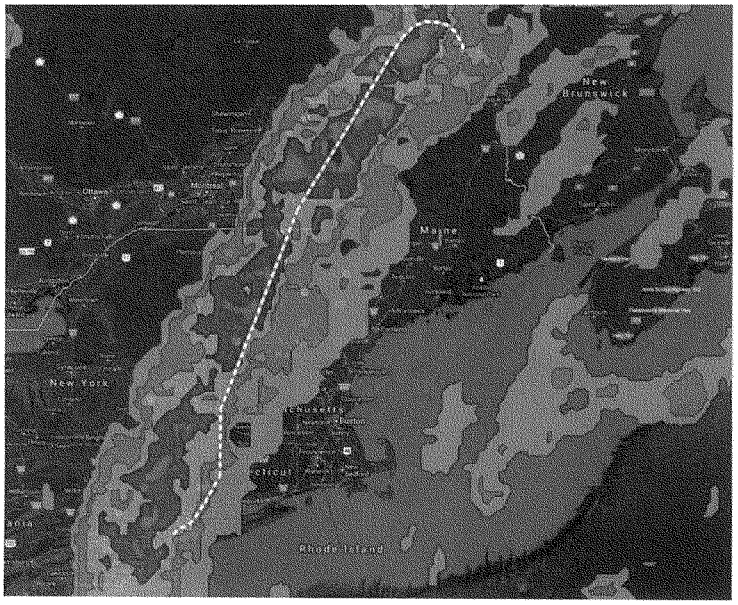
Utilities: We provide services to most large electric utilities such as Florida Power and Light, to predict demand changes relative to weather conditions, and also work with other utilities in what is called "mutual assistance" so they can share work crews for faster power restoration. We also help weather-enable the newest generation of Smart Grid solutions to further optimize the nation's electrical grid.

Transportation: In states hit by winter weather, we make road and pavement forecasts and provide specific guidance of what chemicals to use -- just enough to do the job so that it is both cost effective and environmentally conscious. The City of Fayetteville, AR

and the Illinois Department of Transportation rely on these forecasts to improve transportation operations and make safe weather-related decisions (see Case Studies in Appendix).

Aviation: We provide specific forecasts for airlines including a new turbulence forecast that can predict the location and the effect of turbulence by aircraft type (e.g. Boeing vs. Airbus). An independent laboratory found that our forecast was 20% more accurate with 70% fewer false positives than what the FAA currently uses. We believe there is an opportunity to take advantage of this private sector technology in the modernized airspace system envisioned by the FAA with NextGen.

Turbulence forecast map



Sports: Parts of the southern U.S., such as Florida, have some of the most lightning activity of anywhere in the world. We provide services to the PGA TOUR for lightning safety, along with weather safety information to 350 colleges and universities.

Public Safety: We also provide over 1,000 state and local public safety organizations with weather alerts and forecasts for uses as varied as urban flooding to planning for severe heat spells. The Emergency Management Agency of Butler County, OH chose our weather forecasting system that includes access to expert meteorologists (see Case Studies in Appendix).

Currently, commercial weather services like Schneider Electric's focus on "down-stream" utilization of NOAA data in our solutions to solve specific end-user problems. Conversely, NOAA provides general forecasts and warnings for the overall protection of life and property, along with the observations and numerical weather prediction services that support those activities. This division of services between the private and public sectors of weather is very efficient, and serves the American taxpayer very well. However, it requires cooperation and communication between NOAA and companies like Schneider Electric to work effectively.

Some critics may question the need for a government weather agency at all; however, we strongly disagree. No commercial entity can operate the infrastructure of weather data collection, numerical weather prediction, and universal dissemination that NOAA operates today. At the same time, we also strongly believe the private sector is best placed to use NOAA data to serve the end-use customer. In our view, the multitude and diversity of end-user projects can only be addressed by companies like ours and others, using information from NOAA and other sources.

We offer the following recommendations to drive public-private partnerships and help deliver the best results to communities and taxpayers.

1. There should be more, and *more effective*, cooperation between NOAA and the private sector.

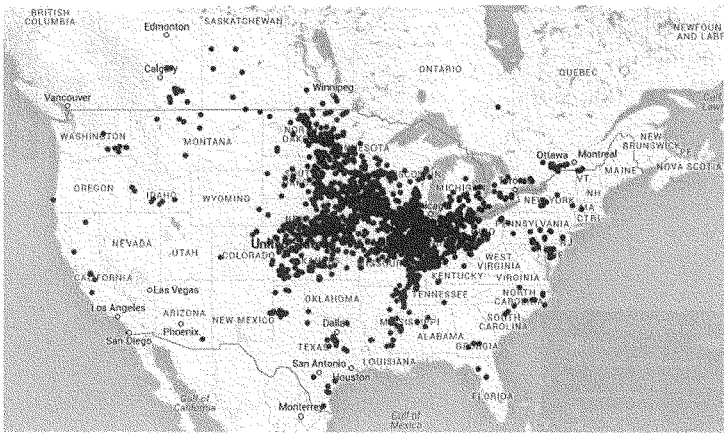
   We believe that strong cooperation between NOAA and the private sector is necessary and long overdue. NOAA should collaborate with its key private sector partners to seek their input and review on any weather related products, services, or projects targeted at private or non-federal public entities, so that the expertise of the private sector and its knowledge of end-user requirements will

ensure that there is not duplication of services. Those private sector partners should be included from the business-to-business community, as well as the consumer sector.

Currently, there is an Environmental Information Services Working Group (EISWG), but its role and impact within NOAA clearly needs to be strengthened, as EISWG appears to have little effect on NOAA practices. We remain agnostic as to whether a new entity or an improved EISWG is a better choice, but one thing is clear – NOAA should leverage the examples of other agencies and have a regular committee or working group that includes permanent private sector members. Downstream private sector entities should be invited to participate in the regular (quarterly) meetings of the EISWG or the next generation of EISWG, plus receive summaries of the group's proceedings.

2. NOAA should place more emphasis on the use of existing data sets from commercial sources.

We believe there is need to look at the relationship between NOAA and downstream service providers, such as Schneider Electric. Those of us who provide weather information to utilities, airlines, farmers, and others strongly benefit from a closer partnership with NOAA. We believe that NOAA can benefit from our specialized data and knowledge of weather information end users. For example, Schneider Electric has built, and now operates, the largest agricultural weather network in the U.S. The Schneider Electric Ag Weather Network consists of more than 4,600 weather stations located on farms, where we collect and manage weather data that is used by farmers to make critical decisions on a daily basis. This information could be a tremendously useful to NOAA.



Nation's Largest Agriculture Weather Station Network (4,600 stations)

A regular and formal meeting or forum between government and the private sector can make NOAA and other government agencies aware of datasets that have been developed by commercial services, with enough technical detail to allow for legitimate evaluation by government agencies. NOAA should provide honest and objective evaluation of these data sets for potential use in their R&D.

3. NOAA should eliminate Decision Support Services that duplicate those available in the private sector.

NOAA should collaborate with its key private sector partners, including private business-to-business partners, and seek their input and review on any Decision Support Services targeted at private or non-federal public entities, so that the expertise of the private sector and its knowledge of end-user requirements will ensure that there is not a duplication of services.

NOAA should refrain from over extending its scope beyond data sets and severe weather warnings. We believe the private sector can and should collaborate with NOAA on any downstream user or business services, with clear

role delineation. For example, NOAA has now started providing road and pavement forecasts that are a complete duplicate of forecasts that have been provided by the private sector for over 30 years (see Case Studies in Appendix). Specialized services like this have a marginal benefit to the public, adversely impact the private sector's ability to innovate and compete, and needlessly tie up taxpayers' dollars (that could be utilized elsewhere) on offers that are already available in the private sector. Closer cooperation with NOAA could avoid such situations.

Government agencies that utilize weather information in their internal processes should be required to review and assess feasibility of use of commercially developed solutions if/when superior results can be achieved. Example: Schneider Electric's new generation turbulence and aircraft icing solutions should be reviewed by the FAA for potential use in upgrading national airspace safety. This solution could be further improved by full use/integration of NOAA modeling input.

As the U.S. population grows and infrastructure expands, increased exposure and vulnerability to these hazards requires risk planning and adaptation for greater resiliency (see Whitepaper in Appendix). We understand and support NOAA's core mission of monitoring the environment and protecting the public. We believe that NOAA's mission can be enhanced and can be more cost-effective if NOAA works more closely with the private sector, uses datasets from outside sources such as the Schneider Electric Ag Weather network, and eliminates duplicative services.

We appreciate the committee for considering our recommendations, and thank you for the opportunity to speak to you today.

Appendix

ForecastWatch Report Summary, Schneider Electric

ForecastWatch Temperature Accuracy Report 2006 – 2015 Results, ForecastWatch

ForecastWatch Short Term Precipitation Accuracy Report 2006 -2015 Results, ForecastWatch

Slide on Ag Weather Network, Schneider Electric

Case Study: Illinois Department of Transportation, Schneider Electric

Case Study: City of Fayetteville, Schneider Electric

Case Study: Butler County, Schneider Electric

Weather Volatility White Paper, Schneider Electric

Ensure top production and operations with our proven forecasts

Life Is On | Schneider Electric

As an energy professional, weather is one of your biggest operational and business concerns — making accurate information critical to your decisions.

Each year, ForecastWatch independently collects and analyzes nearly 5 million forecasts from several U.S. weather service entities, including Schneider Electric.

Every year for the last nine years, we've led the group in one and two-day temperature and precipitation forecast accuracy for the United States. Here are the highlights behind our 2015 top ratings and what greater forecast accuracy can mean to your organization.

TOP-RATED
Short-term temperature & precipitation forecasts
NINE YEARS AND COUNTING! 9

ForecastWatch 2015 Report

Temperature forecasts

Accurate temperature forecasts are essential to supporting quality load forecasts and meeting customer demand. Up to 90 percent of errors can be attributed to inaccurate forecasts. Such errors are costly; just a half a degree difference can result in losses of up to $500,000 per day. Over the course of a year, load forecast errors cost IOUs millions of dollars.

You need the best information possible to better meet customer demand and protect your bottom line. We can help. Our top-rated temperature forecasts support load predictions that most closely reflect actual demand.

ForecastWatch uses root-mean-squared (RMS) error in its independent temperature forecast studies, which heavily penalizes inaccuracy. For example, a forecast that is two degrees off is considered to be four times worse than one that is a single degree off.

Not only have we led in temperature forecast accuracy for the last nine years, we've increased our own accuracy by nearly a half a degree — an improvement of 12.5 percent. This commitment to accuracy and innovation translates into significantly lower costs and increased revenue for our customers.

Precipitation forecasts

For probability of precipitation (POP) forecasts, ForecastWatch measures both accuracy and resolution, providing Brier score-based results. Brier scores range from zero to one, with zero being perfectly accurate. Accuracy in winter is paramount. Snow and ice can significantly impact your service territory and restoration efforts, leaving large numbers of customers without power during cold weather.

For the last nine years, we'd led the group with the lowest Brier score, both during the key winter months and throughout the year. In 2015, our overall score was 0.1078 and our score for the winter months was 0.0958. These were the lowest Brier scores in ForecastWatch's studies to date, and the fifth consecutive year that we improved upon our previous year's score.

12.5%

The amount we've improved our temperature forecast accuracy since our first win in 2006.

792

The number of unique U.S. forecast locations that were featured in ForecastWatch's 2015 POP forecast study.

About ForecastWatch

ForecastWatch is the nation's premier weather forecast monitoring and assessment company. A full service technology consulting firm, it compiles weather forecasts and observations for more than 1,200 locations around the world, including the United States, Canada, Europe, South America, Central America, Africa, and Asia. ForecastWatch also maintains a historical database of more than 400 million weather forecasts from a number of providers.

Read the complete reports at the links below:

Temperature: http://www.forecastwatch.com/static/HighTemps2006-2015.pdf

Precipitation: http://www.forecastwatch.com/static/Short_Term_POP_Accuracy_2015.pdf

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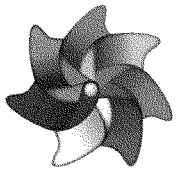

ForecastWatch

Accuracy Defined

Long-Term Analysis of Short-Term High Temperature Forecasts

(September 2006 through September 2015)

By ForecastWatch.com, a Service of Intellovations, LLC
February 4, 2016

Contact:

Eric Floehr
Owner
Intellovations, LLC

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Executive Summary

Since September 2006, ForecastWatch.com has been collecting and verifying high temperature forecasts from the public websites of AccuWeather, CustomWeather, Intellicast, the National Weather Service, The Weather Channel, a forecast feed from the NWS National Digital Forecast Database, Weather Underground, and a forecast feed from Schneider Electric. This year, one- and two-day-out high temperature forecasts were evaluated over approximately 800 locations in the United States between September 1, 2014 and August 31, 2015.

A total of nearly 3.8 million one- and two-day-out high temperature forecasts were collected from seven weather forecast providers and compared with daily high temperature observations from the Automated Surface Observation Network. However, on March 12, 2015, CustomWeather blocked ForecastWatch from accessing it's freely available forecasts at www.myforecast.com. Prior to blocking CustomWeather tended to be near the bottom of overall accuracy.

Over the nine years of this study, almost 40 million forecasts have been collected and compared with observations. Over that nine year period, the weather forecast providers' rankings have remained remarkably consistent. For every year of the study, Schneider Electric's forecasts have had the highest accuracy of all providers.

Why Accurate Temperature Forecasts Are Important

Accurate temperature forecasts are particularly valuable for electric and gas utilities. These weather forecasts are the main driver of their load forecasting, which is used for generation and purchasing decisions. Accurate temperatures pay many benefits including avoiding excessive base loads, reducing spinning reserves and reducing costs overall. Trading and power marketers also greatly benefit from accurate temperature forecasts resulting in smarter market transactions and higher revenues.

Public works departments and state DOTs also benefit from accurate temperature forecasts which are one of the drivers of accurate pavement temperature and frost forecasts. This allows better decision making in crew call-outs, pre-treating roads and overall public safety.

How Temperature Forecasts Are Evaluated

Temperature forecast accuracy is measured a number of ways. All accuracy calculations begin with taking the forecast high temperature and subtracting the actual observed high temperature. This number is called the error. A forecast that predicts too low a temperature will have a negative error, while a forecast that is too high will have a positive error.

Average absolute error is a measure of the accuracy of temperature forecasts. This measure takes the absolute value of the error of each forecast, so that all errors are positive, and then averages all errors. This is a measure of how far off, on average, the set of forecasts is, regardless if they are too high or too low.

Root-mean-squared (RMS) error takes the square of each absolute error, averages all errors for the set of forecasts, and then takes the square root of the average. Samples are weighted linearly in estimating absolute error but as squares in estimating RMS error. Thus, a set of forecasts that show greater variance are penalized more than forecasts with consistent error. Consistent forecast accuracy is very important to industries and government agencies who make decisions based on the weather where lives and livelihoods are at stake.

Results of Temperature Forecast Comparison

The one-day-out high temperature forecast RMS errors in degrees Fahrenheit for the period September 1, 2014 through August 31, 2015 are shown in Table 1. For consumers of forecasts who rely on the most accurate forecasts and where temperature differences can significantly change decision-making, RMS error is usually the best accuracy measurement. With RMS, larger forecast error variability is penalized much more than small forecast error variability. The RMS Error column is the calculated RMS error in degrees Fahrenheit for the period. Rank is the ordered rank of providers for this period (a lower RMS is better).

One-Day-Out High Temperature Forecast Error for period 9/1/2014-8/31/2015

Rank	Provider	RMS Error *(lower is better)*
1	*Schneider Electric*	3.16
2	*AccuWeather*	3.25
3	*The Weather Channel*	3.40
4	*WX Underground*	3.41
5	*Intellicast*	3.54
6	*NDFD*	3.59
7	*NWS Web*	3.96
8	*CustomWeather*	*

Table 1: Results of one year one-day-out high temperature forecast analysis (lower is better)
** – CustomWeather blocked ForecastWatch March 12, 2015*

Two-Day-Out High Temperature Forecast Error for period 9/1/2014-8/31/2015

Rank	Provider	RMS Error *(lower is better)*
1	*Schneider Electric*	3.60
2	*AccuWeather*	3.68
3	*The Weather Channel*	3.78
4	*WX Underground*	3.79
5	*Intellicast*	3.91
6	*NDFD*	4.04
7	*NWS Web*	4.36
8	*CustomWeather*	*

Table 2: Results of one year two-day-out high temperature forecast analysis (lower is better)
** – CustomWeather blocked ForecastWatch March 12, 2015*

There was a 0.80 degree Fahrenheit (0.44 degree Celsius) difference between the least accurate provider (the NWS website) and the most accurate provider (Schneider Electric), which was slightly less than last year. The two-day-out high temperature forecast RMS errors are shown in Table 2. The two-day-out results are similar to the one-day-out results, with all providers having the same relative rank as the one-day-out results. Overall, error for two-day-out forecasts are greater than one-day-out forecasts, as expected. On average, there is an approximately 0.40 degree Fahrenheit (0.22 degree Celsius) increase in error between the one- and two-day-out high temperature forecasts.

The spread between first and last place was 0.76 degree Fahrenheit (0.42 degree Celsius) for two-day-out forecasts. For both one- and two-day-out high temperature forecasts, the difference in accuracy between first and last place providers is nearly a degree Fahrenheit. For companies where a degree of difference in a forecast can have life-and-death or monetary implications, it is clear that selecting the right forecast provider and continually monitoring their forecasts is important.

Nine Year Comparison

For the ninth year, Schneider Electric had the lowest RMS error. While the gap between first and last place remains large, all providers except Schneider Electric lowered their RMS error from the previous year. AccuWeather had the largest improvement in accuracy, moving from seventh place to second place in both one- and two-day-out accuracy. AccuWeather's one-day-out RMS error improved 0.59 degree Fahrenheit (0.33 degree Celsius) and two-day-out RMS error improved 0.54 degree Fahrenheit (0.30 degree Celsius). These were the largest year-over-year improvements in forecast accuracy for any provider over the nine year study period.

One-Day-Out High Temperature Forecast Error By Year

Year	Schneider Electric		Accu-Weather		TWC		WXU		Intellicast		NDFD		NWS Web		Custom-Weather	
2014-2015	3.16	1	3.25	2	3.40	3	3.41	4	3.54	5	3.59	6	3.96	7		
2013-2014	3.15	1	3.84	7	3.52	2	3.60	3	3.67	4	3.71	5	4.06	8	3.72	6
2012-2013	3.25	1	3.73	6	3.28	2	3.75	7	3.42	3	3.50	4	3.90	8	3.67	5
2011-2012	3.34	1	4.06	7	3.40	2	3.93	5	3.48	3	3.60	4	3.95	6	4.08	8
2010-2011	3.44	1	4.27	8	3.70	2	4.07	6	3.74	4	3.72	3	4.02	5	4.21	7
2009-2010	3.25	1	4.06	8	3.52	2	3.75	5	3.57	4	3.53	3	3.86	7	3.84	6
2008-2009	3.45	1	4.31	8	3.91	3	4.12	5	3.97	4	3.84	2	4.14	6	4.23	7
2007-2008	3.68	1	4.29	7	3.83	2			3.89	4	3.87	3	3.99	5	4.09	6
2006-2007	3.60	1	4.18	7	3.71	2			3.77	4	3.75	3	3.92	5	4.02	6

Table 3: Nine year comparison of one-day-out high temperature forecast error (lower is better)

Table 3 lists the one-day-out rankings and RMS error for all nine year-long periods. After accounting for AccuWeather's move from seventh to second place, other providers' relative rankings remained the same again this year. The Weather Channel, Weather Underground, Intellicast, the National Digital Forecast Database, and the NWS website forecasts all lowered their RMS error from the previous year. While the overall trend for all providers is positive, only AccuWeather and Weather Underground obtained their lowest forecast error over the nine year study period this year.

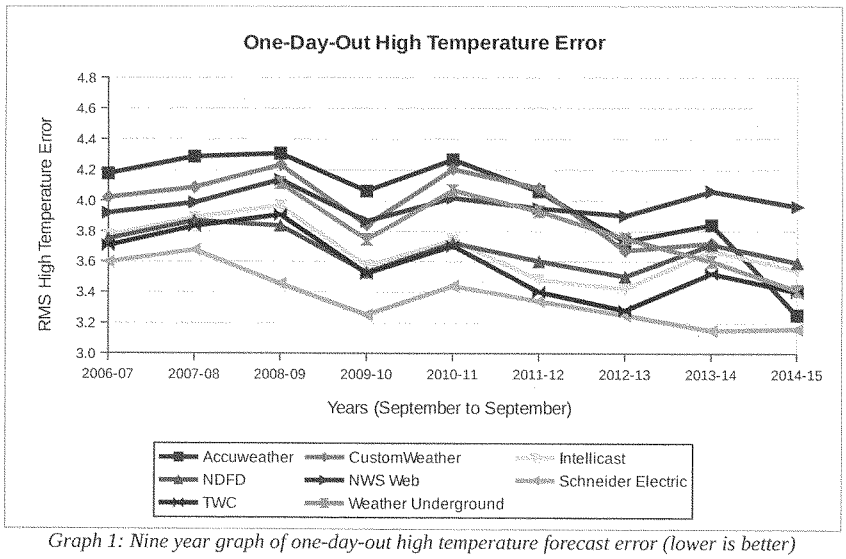
Two-Day-Out High Temperature Forecast Error By Year

Year	Schneider Electric		Accu-Weather		TWC		WXU		Intellicast		NDFD		NWS Web		Custom-Weather	
2014-2015	3.60	1	3.68	2	3.78	3	3.79	4	3.91	5	4.04	6	4.36	7		
2013-2014	3.59	1	4.22	7	3.92	2	4.00	3	4.05	4	4.08	5	4.38	8	4.11	6
2012-2013	3.70	1	4.13	6	3.72	2	4.17	7	3.83	3	3.89	4	4.23	8	4.01	5
2011-2012	3.85	1	4.42	7	3.88	2	4.37	6	3.94	3	4.03	4	4.35	5	4.43	8
2010-2011	3.92	1	4.63	8	3.70	3	4.45	6	4.20	4	4.12	2	4.39	5	4.57	7
2009-2010	3.70	1	4.45	8	3.97	2	4.17	5	4.00	4	3.97	3	4.25	6	4.27	7
2008-2009	3.97	1	4.76	8	4.34	3	4.59	6	4.43	4	4.33	2	4.57	5	4.67	7
2007-2008	4.20	1	4.67	7	4.32	2			4.39	4	4.37	3	4.47	5	4.50	6
2006-2007	4.13	1	4.64	7	4.20	2			4.29	3	4.29	4	4.44	5	4.54	6

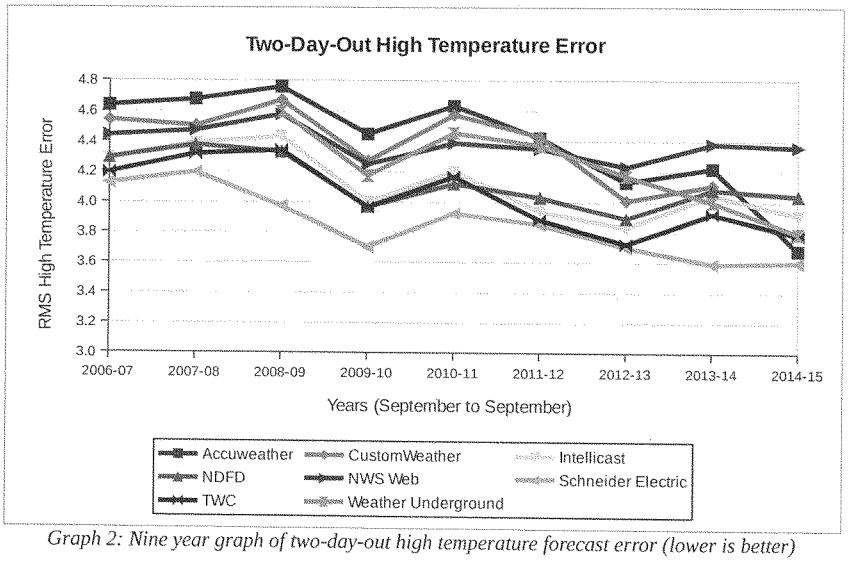
Table 4: Nine year comparison of two-day-out high temperature forecast error (lower is better)

Table 4 lists the two-day-out rankings and RMS error for all nine years. Like the one-day-out year-over-year results, AccuWeather moved from seventh to second, moving the other providers down one rank. For the two-day-out results, only AccuWeather and Weather Underground achieved their lowest RMS error for the entire nine years this year, while The Weather Channel tied their best year. Schneider Electric, for both one-day-out and two-day-out results, missed their best year this year by just 0.01 degree Fahrenheit (0.006 degree Celsius).

The two line graphs, Graph 1 and Graph 2, illustrate the changes in high temperature forecast error over the nine year study period and the accuracy differences between providers. Graph 1 shows the nine year history of high temperature forecast RMS error for one-day-out forecasts, while Graph 2 shows the nine year history for two-day-out forecasts. The y-axis of both graphs do not begin at zero, in order to highlight differences and trends in accuracy over the nine-year period, however the vertical scale of both graphs is identical.



Graph 1: Nine year graph of one-day-out high temperature forecast error (lower is better)



Graph 2: Nine year graph of two-day-out high temperature forecast error (lower is better)

Methodology of the Comparison

Daily high temperature forecasts were collected from each provider starting at 22:00 UTC (6pm Eastern Standard Time) and continuing until all forecasts are collected. For each location, forecasts from all providers were collected at the exact same time. Forecasts from AccuWeather were collected from the AccuWeather API at http://apidev.accuweather.com/developers/. Intellicast was collected from http://www.intellicast.com, The Weather Channel (TWC) forecasts were from http://www.weather.com, and the National Weather Service forecasts from http://www.weather.gov. The NDFD forecasts were collected using a SOAP interface at http://www.weather.gov/ndfd/. Weather Underground forecasts were collected from http://www.wunderground.com.

A one-day-out high temperature forecast is the forecast for the next day, whereas the two-day-out forecast is for the day after that. For example, for a forecast collected on January 1, 2015, the one-day-out high temperature forecast would be the forecast for January 2, 2015, and the two-day-out forecast would be the forecast for January 3, 2015.

Provider	Number of Forecasts	Percent of Possible Forecasts
AccuWeather	271,122	93.8%
CustomWeather	*	*
Intellicast	272,488	94.3%
NDFD	270,238	93.5%
NWS Web	262,413	90.8%
Schneider Electric	272,493	94.3%
The Weather Channel	270,912	93.7%
WX Underground	271,899	94.1%

Table 5: Number of one-day-out forecasts analyzed and percent of possible, by provider
** – CustomWeather blocked ForecastWatch March 12, 2015*

Provider	Number of Forecasts	Percent of Possible Forecasts
AccuWeather	271,084	93.8%
CustomWeather	*	*
Intellicast	272,446	94.2%
NDFD	270,215	93.5%
NWS Web	262,568	90.8%
Schneider Electric	272,449	94.2%
The Weather Channel	270,876	93.7%
WX Underground	271,881	94.1%

Table 6: Number of two-day-out forecasts analyzed and percent of possible, by provider
** – CustomWeather blocked ForecastWatch March 12, 2015*

For this study, the 24-hour high temperatures as reported by the observation stations in the ASOS/AWOS observation network maintained by the National Weather Service and the Federal Aviation Administration were used. These observations were collected from the Quality-Controlled Local Climatic Data (QCLCD) product from the National Climatic Data Center (NCDC).

The Root-Mean-Squared (RMS) error was calculated by subtracting the high temperature observation from the high temperature forecast, and that value was squared. The square root of the average of all the squared errors for each year was calculated, and that is the value shown in the report. Each yearly period includes forecasts collected September 1 through August 31 the following year.

There were around 270,000 forecasts used for each provider and year. The percent of possible forecasts collected and compared is less than 100% because of invalid forecasts, problems in collecting forecasts successfully, and days in which observations were not available for a particular site.

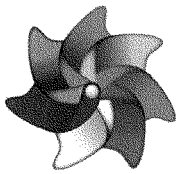
Table 5 shows the number of forecasts collected and compared for each provider for one-day-out forecasts, and Table 6 shows the same for two-day-out forecasts. Differences in the forecast count are due to a number of factors. First, invalid forecasts are removed. Second, occasionally a provider's website or feed would be off-line or not be complete due to network issues, production issues in the provider's forecast creation, or other issues. For example, the relatively lower number of NWS web forecasts is primarily due to quality issues (invalid forecasts) and website availability issues (the weather.gov site was unavailable or could not provide a forecast). Finally, ASOS/AWOS stations are down and don't provide data for a day or two every few months due to maintenance. Overall, around 93.5% of the possible forecasts and observations that could be compared for each provider were able to be compared.

About ForecastWatch.com

ForecastWatch is the nation's premier weather forecast monitoring and assessment company. A full-service, technology consulting firm, ForecastWatch compiles weather forecasts and observations at more than 1,200 locations around the world, including the U.S., Canada, Europe, South America, Central America, Africa and Asia Pacific. ForecastWatch also maintains a historical database of over 500 million weather forecasts from a number of providers.

ForecastWatch data and analysis has been used by meteorologists, utilities and energy companies, the agriculture industry, futures traders, and others whose business success depends on being right about the weather. Our data meets the highest standard of scientific inquiry, and has been used in several peer-reviewed studies, including a paper published in the Monthly Weather Review. In 2003, ForecastWatch.com released the largest public weather forecast accuracy study undertaken to that point.

ForecastWatch services have been used to evaluate weather forecast providers, improve decision-making where weather forecasts are used as input, improve weather forecasts by providing useful feedback, compare weather forecast performance between providers, educate customers with unbiased reporting, and improve the quality of weather forecast websites.



ForecastWatch

Accuracy Defined

Long-Term Analysis of Short-Term Probability of Precipitation Forecasts

(July 2006 through June 2015)

By ForecastWatch.com, a Service of Intellovations, LLC
February 11, 2016

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Executive Summary

Since October 2006, ForecastWatch has been collecting and verifying probability of precipitation forecasts from CustomWeather, The National Weather Service, The Weather Channel, Weather Underground, and a non-public feed from Schneider Electric (collected at the same time as the public forecasts) against actual observations from the ASOS national weather observation network. This year, one-day-out probability of precipitation (POP) forecasts were evaluated over approximately 800 locations in the United States between July 1, 2014 and June 30, 2015.

A total of almost 1.1 million one-day-out probability of precipitation forecasts were collected over the year-long period, and approximately 12 million forecasts have been collected over the nine years of the study. However, on March 12, 2015, CustomWeather blocked ForecastWatch from accessing it's freely available forecasts at www.myforecast.com. Prior to blocking CustomWeather tended to be near the bottom of overall accuracy. For nine straight years, Schneider Electric had the best scores for the year-long POP accuracy period, as well as for the winter months only.

Importance of POP Forecasts

Many organizations rely on good precipitation forecasts. Concrete pouring and asphalting decisions depend on reliable rain forecasts. Missing the rain can result in costly re-dos, while forecasting rain when there ends up being none results in lost revenue opportunities. Public works departments and state DOTs rely on accurate snow and ice forecasts to know when to call out crews and pre-treat roads. For them reliable forecasts are critical for public safety, and for avoiding unnecessary and costly crew call outs.

Accurate precipitation forecasts are similarly important to electrical utilities, airports, golf courses, outdoor sports and recreation, and police/emergency management. Accurate precipitation forecasts add to the bottom line of weather-dependent businesses. And they help cities, counties and other organizations better meet their mission.

How POP Forecasts Are Evaluated

There are two components to measuring the accuracy of a probability-of-precipitation forecast. The first is accuracy. If, over the forecasts being measured, there was precipitation the same percentage of time as forecast, the forecast is said to be *accurate*. For example, if it rained 10% of the time the POP forecast called for a 10% chance of rain, the POP forecasts would be accurate. If, on average, there is precipitation three out of ten days at a given location, and the forecaster always predicted a 30% chance of precipitation every day, the forecaster would be accurate. While accurate, the forecast isn't useful.

The second measure of a POP forecast is *resolution*. A perfectly resolved POP forecaster would always predict no chance of precipitation for dry days, and 100% precipitation for days on which there was rain or snow. The forecaster above who always forecast a 30% chance of precipitation would be said to be fully *unresolved*. However, a forecaster who predicted 100% chance of precipitation on dry days, and zero percent on wet ones is still perfectly resolved, but completely inaccurate. While resolved, the forecast isn't useful.

Evaluating a POP forecast fully, therefore, must take both the accuracy and the resolution of the forecast into account. The calculation used to evaluate POP forecasts is called the Brier score. The Brier score takes both accuracy and resolution into account. A Brier score ranges from zero to one, with zero being perfectly accurate and resolved (0% POP forecast on dry days, 100% POP forecast on days with precipitation).

Results of Short-Term POP Forecast Comparison

The following tables detail the Brier scores for each weather forecast provider for one-day-out probability of precipitation forecasts. Table 1 shows Brier scores for the one-year period of July 1, 2014 through June 30, 2015. This year we made a change to how we interpret National Weather Service POP forecasts (note b). Prior to this year, we interpreted NWS forecasts without a POP forecast as a POP forecast of 0%. However, that is not true, as the NWS will in certain regions and under certain conditions, not show a POP if their forecasted POP is 20% or lower. Therefore, interpreting a missing POP as 0% chance of precipitation is incorrect. This year, we only evaluated NWS forecasts that contained a POP.

This year, Schneider Electric again had a lower Brier score than all public forecasts collected by ForecastWatch in the United States, and has maintained that rank for all nine years of the study.

Rank	Provider	Brier Score *(lower is better)*
1	*Schneider Electric*	0.1078
2	*Weather Underground*	0.1223
3	*The Weather Channel*	0.1230
4	*National Weather Service*	0.2111[b]
5	*CustomWeather*	*

Table 1: Results of one year (July 2014–June 2015) short-term POP forecast analysis (lower is better)
** CustomWeather blocked ForecastWatch on March 12, 2015*

Many businesses, governments, and individuals are especially interested in winter forecasts. Preparations for snow or ice, such as changing business processes, salting roads in advance, or keeping employees on standby are real costs. Better prediction of winter precipitation results in money saved, better service, and improved planning for those businesses, governments, and individuals.

POP scores for the winter months of December 2014 through February 2015 have been broken out in Table 2. Schneider Electric forecasts led all collected public forecasts for the winter months, and it has led for all nine years of the study.

Rank	Provider	Brier Score *(lower is better)*
1	*Schneider Electric*	0.0958
2	*The Weather Channel*	0.1152
3	*Weather Underground*	0.1154
4	*CustomWeather*	0.1155
5	*National Weather Service*	0.2035[b]

Table 2: Results of short-term POP forecast analysis for winter 2014-2015 (lower is better)

Nine Year Comparison

This is the ninth year that this POP study has been conducted. Table 3 shows full-year Brier scores for each of the nine years. This year, Schneider Electric and The Weather Channel had their lowest (and best) Brier scores for the entire period. This is the fifth year in a row Schneider Electric has improved their Brier score for POP forecasts, and is unmatched by any other provider in the study.

Year	Schneider Electric		WX Underground		The Weather Channel		NWS		Custom-Weather	
Jul 2014 – Jun 2015	0.1078	1	0.1223	2	0.1230	3	0.2111[b]	4		
Jul 2013 – Jun 2014	0.1090	1	0.1247	3	0.1415	5	0.1244	2	0.1252	4
Jul 2012 – Jun 2013	0.1115	1	0.1209	2	0.1315	5	0.1242	4	0.1217	3
Jul 2011 – Jun 2012	0.1163	1	0.1778	5	0.1288	4	0.1288	3	0.1258	2
Jul 2010 – Jun 2011	0.1260	1			0.1390	3	0.1393	4	0.1351	2
Jul 2009 – Jun 2010	0.1330	1	0.1534	5	0.1468	3	0.1486	4	0.1386	2
Jul 2008 – Jun 2009	0.1290	1	0.1458	5	0.1399	3	0.1428	4	0.1329	2
Jul 2007 – Jun 2008	0.1300	1			0.1459	3	0.2182[a]	4	0.1379	2
Oct 2006 – Jun 2007	0.1219	1			0.1382	3	0.1903[a]	4	0.1271	2

Table 3: Nine-year comparison of one year short-term POP forecast analysis (lower is better)

Note that the Weather Underground redesigned their site in February 2011 which temporarily removed POP forecasts for the June 2010 – June 2011 period. Because we could not collect a full year of forecasts for them, they were not included in the study that period. CustomWeather blocked ForecastWatch collection on March 12, 2015, so a full year could not be compared.

Winter Season	Schneider Electric		The Weather Channel		WX Underground		Custom-Weather		NWS	
Dec 2014 – Feb 2015	0.0958	1	0.1152	2	0.1154	3	0.1155	4	0.2035[b]	5
Dec 2013 – Feb 2014	0.0971	1	0.1569	5	0.1174	4	0.1164	3	0.1128	2
Dec 2012 – Feb 2013	0.1052	1	0.1307	5	0.1206	2	0.1216	3	0.1237	4
Dec 2011 – Feb 2012	0.1008	1	0.1198	5	0.1167	2	0.1180	4	0.1177	3
Dec 2010 – Feb 2011	0.1145	1	0.1272	4			0.1252	3	0.1249	2
Dec 2009 – Feb 2010	0.1183	1	0.1277	3	0.1345	5	0.1223	2	0.1303	4
Dec 2008 – Feb 2009	0.1194	1	0.1275	3	0.1458	5	0.1204	2	0.1300	4
Dec 2007 – Feb 2008	0.1224	1	0.1445	3			0.1363	2	0.2017[a]	4
Dec 2006 – Feb 2007	0.1104	1	0.1846	4			0.1228	2	0.1351[a]	3

Table 4: Nine-year comparison of winter season short-term POP forecast analysis (lower is better)

Please also note (a) that The National Weather Service scores for 2006-2007 and 2007-2008 were calculated on a small percentage of POP forecasts relative to the other providers, due to NWS website forecast issues which were corrected in 2008 when the NWS began migrating to point forecasts on its website. For 2014-2015 only National Weather Service scores forecasts that provided a POP forecast were evaluated, no attempt to assign a POP forecast to forecasts without a POP were made.

Table 4 shows the nine year winter month data. The winter-only rankings are similar to the full-year rankings. Schneider Electric had the lowest Brier score this year, and has improved its score six out of the last seven years. This year, Schneider Electric also achieved the lowest Brier score measured in the nine years of the study.

Methodology of the Comparison

Brier scores are more useful the larger number of forecasts and observations there are to calculate. This study evaluated POP forecasts for 792 locations within the United States over the period of July 1, 2014 through June 30, 2015. Forecasts were collected starting at 22:00 UTC (6pm Eastern Standard Time) and continuing until all forecasts are collected. For each location, forecasts from all providers were collected at the exact same time. A forecast without a probability of precipitation value was not evaluated and no attempt at assigning a POP value was attempted. Forecasts with invalid POP percentages (less than 0% or greater than 100%) were declared invalid and not included. Forecasts declared invalid through ForecastWatch's extensive audit process (i.e. bad high or low temperatures) were also not included.

Provider	Number of Forecasts	Percent of Possible Forecasts
CustomWeather	*	*
NWS	262,171	90.7%
Schneider Electric	272,161	94.1%
The Weather Channel	270,571	93.6%
Weather Underground	270,810	93.7%

Table 5: Number of forecasts collected during the period and percent of possible, by provider

Provider	Number of Forecasts	Percent of Possible Forecasts
CustomWeather	64,594	90.6%
NWS	63,048	88.5%
Schneider Electric	64,946	91.1%
The Weather Channel	64,932	91.1%
Weather Underground	64,806	90.9%

Table 6: Number of forecasts collected during the winter period and percent of possible, by provider

The forecasts were compared against daily 24-hour local time precipitation measured by the ASOS/AWOS observation network maintained by the National Weather Service and the Federal Aviation Administration. If 0.01 inches of liquid-equivalent precipitation or more fell that in that day, it was considered to have been a precipitation event. The percent of possible forecasts collected and compared is less than 100% because of invalid forecasts, problems in collecting forecasts successfully, and days in which observations were not available for a particular site.

Despite the occasional collection problem or invalid forecasts, collection rates for the full year were above 93% for all providers except The National Weather Service. The National Weather Service website does not publish POP values for about 20 locations which don't produce a point forecast, which keeps their rates a little lower than the other providers. Collection rates for the 90 day winter period from December 1, 2014 through February 28, 2015 are also above 90% except for NWS.

About ForecastWatch.com

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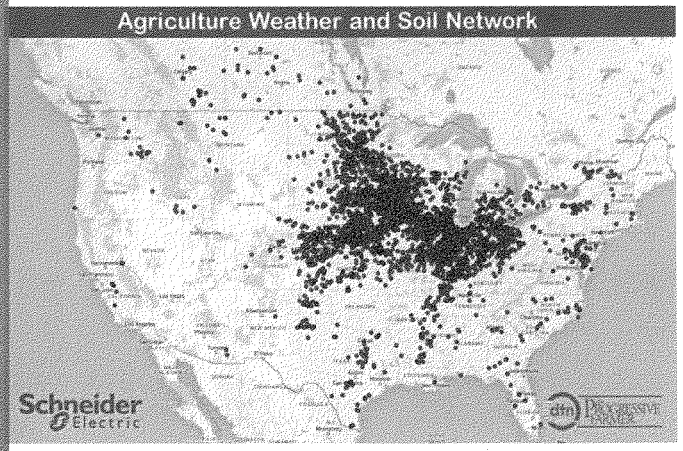
ForecastWatch data and analysis has been used by meteorologists, utilities and energy companies, the agriculture industry, futures traders, and others whose business success depends on being right about the weather. Our data meets the highest standard of scientific inquiry, and has been used in several peer-reviewed studies, including a paper published in the Monthly Weather Review. In 2003, ForecastWatch.com released the largest public weather forecast accuracy study undertaken to that point.

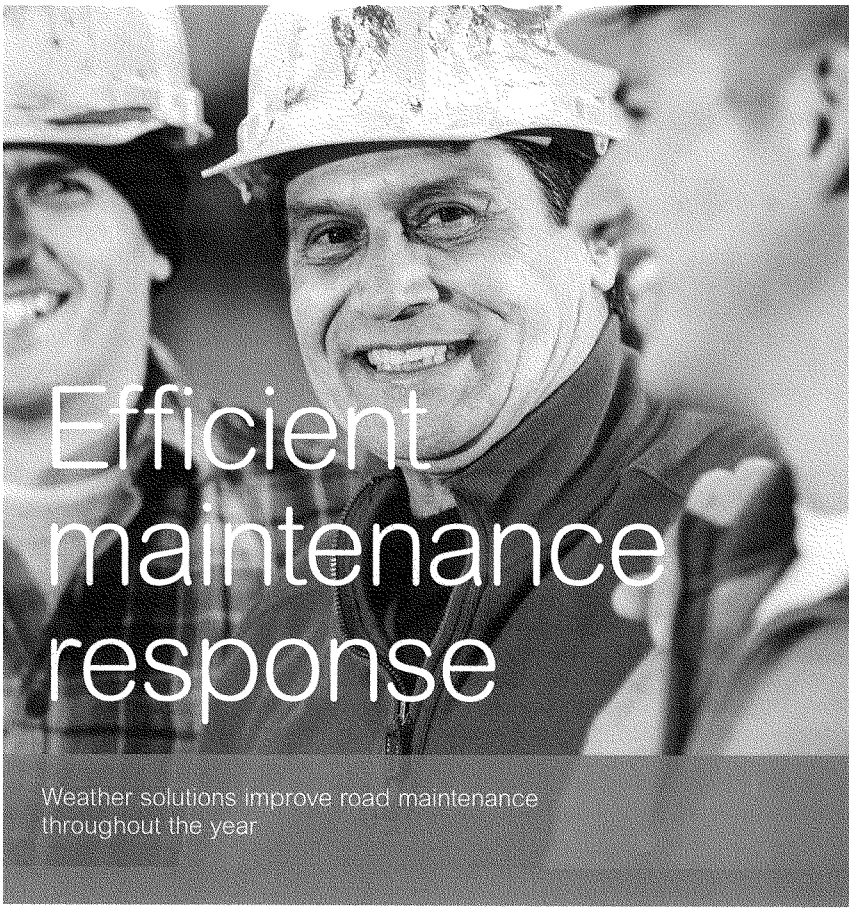
ForecastWatch services have been used to evaluate weather forecast providers, improve decision-making where weather forecasts are used as input, improve weather forecasts by providing useful feedback, compare weather forecast performance between providers, educate customers with unbiased reporting, and improve the quality of weather forecast websites.

Ag Weather Network

- **Agricultural Weather and Soil Network**
- **Supporting Precision Ag with field level weather**
  - 4,000 stations today
  - 7,000 by the end of 2016
- **FUTURE:**
  - Looking to add soil temp and moisture sensors



Life Is On Schneider Electric



Illinois Department of Transportation (DOT)
Springfield, Illinois

schneider-electric.com

Life Is On | Schneider Electric

The Illinois DOT is responsible for winter and summer maintenance of 45,839 lane miles statewide. This includes all state highways, federal aid routes and the Illinois interstate system.

Challenges

Providing a safe and effective road system for the motoring public is extremely challenging during winter's snow and ice storms. Spring floods often result in road closures, and rain and heat can interrupt summer maintenance tasks, such as striping, mowing and chemical applications.

Solution

Schneider Electric provided Illinois DOT central headquarters with WeatherSentry, which is networked in the main office, as well as provided to team section locations with weather display systems. In addition, display systems were installed in Illinois rest areas, providing state-specific weather information to the travelling public.

Schneider Electric products provide accurate, highly local, real-time weather at the touch of a button. It's an easy-to-use, intuitive system that enables maintenance managers to quickly make informed weather-related decisions. WeatherSentry provides weather display capabilities plus powerful storm tracking and real-time visual weather alerts. "These Schneider Electric products enable us to track storms as they're occurring so we can make informed judgments as to how the storms are progressing," said Tim Peters, equipment engineer. "We can make staffing decisions and schedule maintenance activities based on the weather."

Goal

Improve operational weather solutions

Solution

Improves transportation operations and weather-related safety decisions

Equipment

WeatherSentry®

Results

- Improve crew scheduling
- Ensure safer roadways
- Enhance chemical applications
- Reduce operational costs

The Bottom Line

The display systems installed in the Illinois interstate rest areas contain a scrolling screen saver pre-programmed with basic weather information, as well as custom screens showing Illinois road construction and weather-related road conditions in the state. "We've got positive comments from the motoring public in surveys we've done on the quality of that information," said Peters.

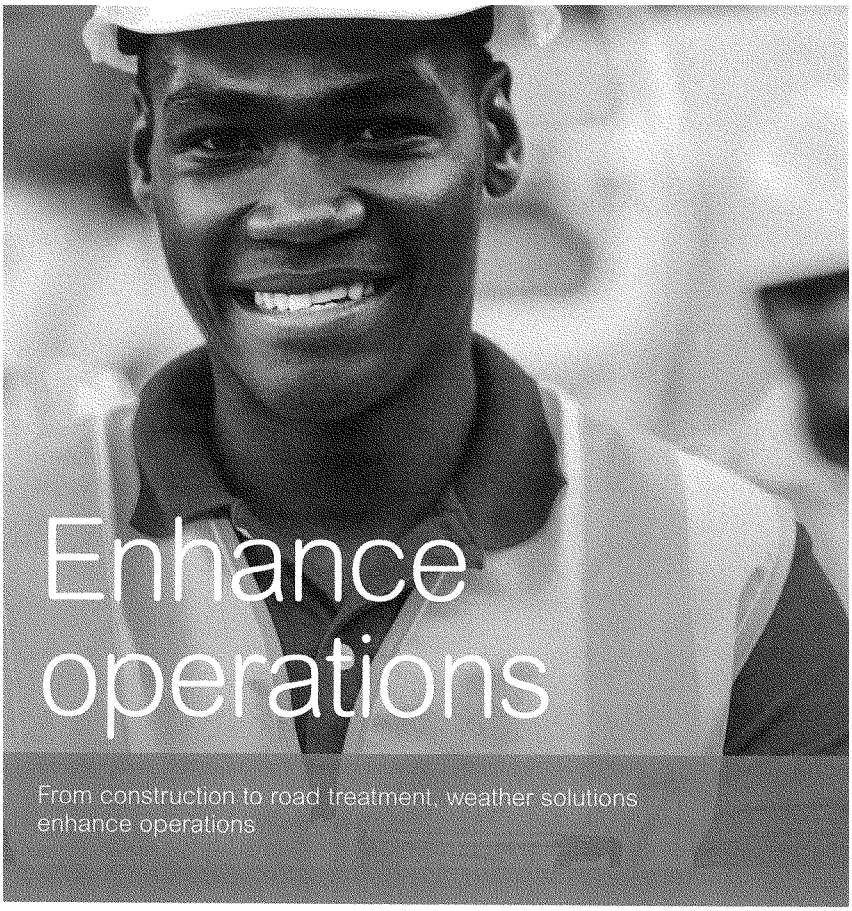
The Schneider Electric systems enable the Illinois DOT to manage staffing levels and support resources more efficiently. "The information we receive allows us to more effectively respond to storms, which benefits Illinois taxpayers," he said. "We can refine staffing levels and adjust parameters of what employees are doing based on what we see."

In the winter, the information is used to monitor snowfall, temperatures, and wind as storms are occurring ,so they can determine how much salt to apply, how many people are needed to keep roadways clear and safe, and when to call in crews after the storm has passed.

In the summer months, forecast information is used by maintenance personnel as they plan minor road repair, mowing and weed spraying. During the spring flooding season, Illinois DOT personnel use the Schneider Electric rainfall information to support the efforts related to flooding. Illinois DOT's flood response efforts also involve the Illinois Emergency Management Agency and Department of Natural Resources.

"Schneider Electric products enable the Illinois DOT to get high-quality weather information out in the field. It's an excellent tool for maintenance to get real-time weather data, as well as forecast information. We have one in the lower lobby of our building, and people stop to check the weather all the time."

- Tim Peters, Illinois Department of Transportation



City of Fayetteville
Fayetteville, Arkansas

schneider-electric.com

Life Is On | Schneider Electric

Fayetteville, Arkansas, has a population of 70,000. The city's public works department is responsible for year-round maintenance of 420 miles of city streets, in addition to helping with some state roads. They employ a full-time crew of 65.

Challenges

Due to the Arkansas climate, ice is Fayetteville's main weather challenge in the winter. They needed a system that shows them when rain will change to ice or snow, as well as pavement forecasts so that they know when rain on streets will freeze. Fayetteville sits in a mountainous area of the state, and storms vary from system to system — they may have rain on one side of the county, and ice on the other. The city experiences approximately five or six ice events per year.

Fayetteville also needed accurate precipitation forecasts for their paving and concrete work during the summer months, as they cannot lay asphalt or concrete when it is raining.

Solution

The city of Fayetteville selected the professional package of WeatherSentry Online. The professional package includes access to weather and pavement forecasts, both online and via a mobile device. They also have access to real-time lightning information, alerts and the ability to access a meteorologist any time of the day or night.

As a powerful add-on to the professional package, the city subscribes to RoadCast pavement forecasts. Roadcast determines current and forecasted pavement temperature, which helps them decide which treatment to use to de-ice and clear snow from city roads.

Goal

Improve operational weather solutions

Solution

Improves transportation operations and weather-related safety decisions

Equipment

WeatherSentry Online®
Transportation Edition
RoadCast® pavement temperature forecasts

Results

- Ensure safer roadways
- Improve crew scheduling
- Enhance the timing and rate of chemical applications
- Better manage salt and labor costs to protect their bottom line
- Time work involving asphalt and concrete to better manage costs

The Bottom Line

"We use the radar to watch a front come in," said Joey Smith, field operations supervisor for the City of Fayetteville. "It helps us when we're working outside, as we're able to see to see storms approaching our area. By watching the radar and monitoring the forecasts, we can determine what actions we need to take for each storm."

The hourly forecasts are particularly useful to Smith. "The hourly forecasts help me determine if I need to send a crew out early to pretreat," he stated. "I prefer to utilize my day crew to pretreat."

Fayetteville needs the most accurate weather and pavement forecasts available, as each storm's unique conditions affect how they will react. "We use salt brine primarily, but when it's raining out, the salt brine just washes away. In this case, we spread rock salt instead, and as the rain melts the salt, it activates itself," Smith said.

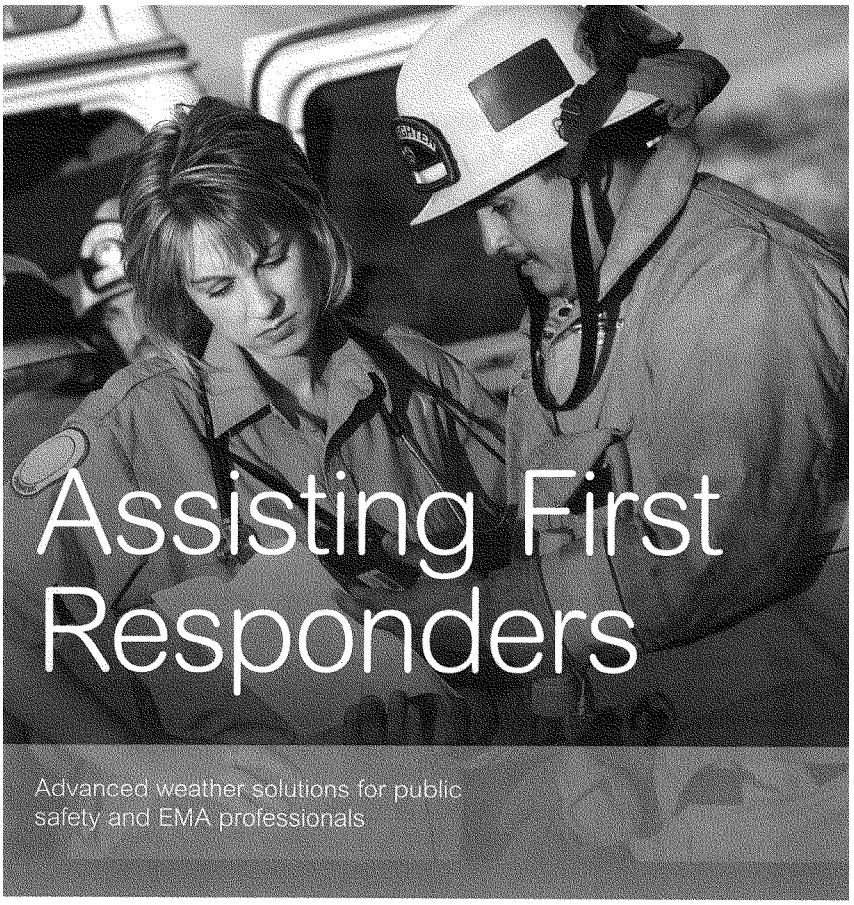
Smith takes advantage of the fact he can access critical weather information and alerts anywhere on his mobile device. "I can receive alerts when out and about," he remarked. "I don't have to be in the office to know when I need to call in crews."

The city's subscription to RoadCast pavement forecasts is beneficial in allowing them to monitor pavement temperatures in locations on the north and west sides of town, as storms typically come in from the northwest. Fayetteville has four RoadCast points throughout the county, showing the pavement temperature at those locations.

The public works department in Fayetteville uses Schneider Electric's weather information and alerts year-round. Their system is utilized in summer when crews are paving. "I can't lay asphalt or pour concrete when it's raining," said Smith. "We use asphalt every day in the summer months, and it's very expensive. The system helps us to avoid costly, weather-related mistakes."

"Having access to accurate pavement temperatures is key — if temperatures stay above freezing, I can avoid the cost of sending out a crew overnight."

- Joey Smith, field operations supervisor, City of Fayetteville



Emergency Management Agency of Butler County
Hamilton, Ohio

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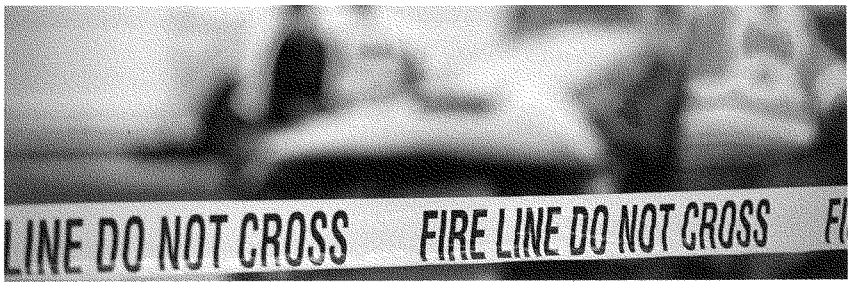


The Emergency Management Agency (EMA) of Butler County, headquartered in Hamilton, Ohio, assists the community in disaster and emergency management. Through disaster preparedness education, monitoring of threatening events, and public safety-related emergency management activities, the agency ensures a safer public and community.

Challenge

The EMA of Butler County sought a weather forecasting system that included access to expert meteorologists who could provide detailed explanations of weather forecasts and potential impacts of severe weather on the community.

Solution

The EMA of Butler County chose the Schneider Electric WeatherSentry Public Safety Edition, designed exclusively for public safety and EMA professionals to help with catastrophic weather events, storm tracking, HAZMAT incidents, terrorism, and flood management. It provides advanced weather forecasts, tools, and alerts to help plan responses and mitigate damage caused by tornadoes, severe thunderstorms, floods, snow and other severe weather.

WeatherSentry Public Safety Edition supplies the EMA of Butler County with accurate, detailed forecasts based on a proprietary forecasting system, which is managed 24/7 by experienced meteorologists. Conditions are forecasted up to 15 days out, with hourly outlooks for the first three days. For eight consecutive years, Schneider Electric precipitation and temperature forecasts outperformed others in the industry in an independent study by ForecastWatch.com.

Goal

Improve operational weather systems

Solution

Around-the-clock meteorological support for weather event response and incident management team dispatch

Equipment

WeatherSentry® Online Platinum, Public Safety Edition

Results

- Keeps citizens and first responders safer
- Improves and supports coordinated responses to severe weather
- Provides access to meteorologists 24/7

The EMA of Butler County is able to consult with a team of experienced meteorologists at any time from a computer or mobile device. Users can ask a question, discuss a forecast, and view the questions of industry peers to gain a better understanding of a forecast.

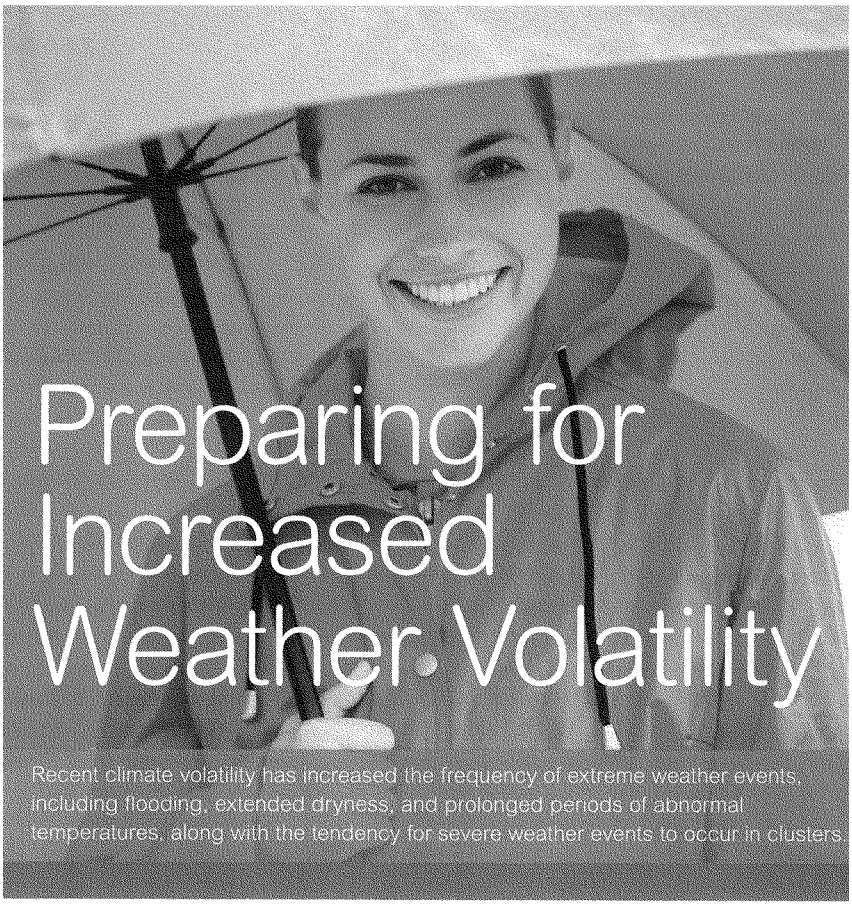
The Bottom Line

The EMA of Butler County leverages the discussions and briefings with meteorological staff to better prepare for weather events and to dispatch teams accordingly. Available around the clock, these experts help staff better prepare for severe weather events and dispatch the right teams at the right time, such as Butler County's all-hazards incident management team or other teams that respond to events outside of Butler County.

"We deploy teams around the country to help with other natural disasters, like wildfires out West and Hurricane Sandy," explained Matt Haverkos, director of the EMA of Butler County. "So we're constantly watching the weather updates and for changes to the forecasts. Being able to talk with the meteorologists directly and having access to their briefings has been very helpful."

"WeatherSentry's meteorologist services are why we chose Schneider Electric. The cost was right and they add a lot of value to our services."

- Matt Haverkos, director of the EMA of Butler County



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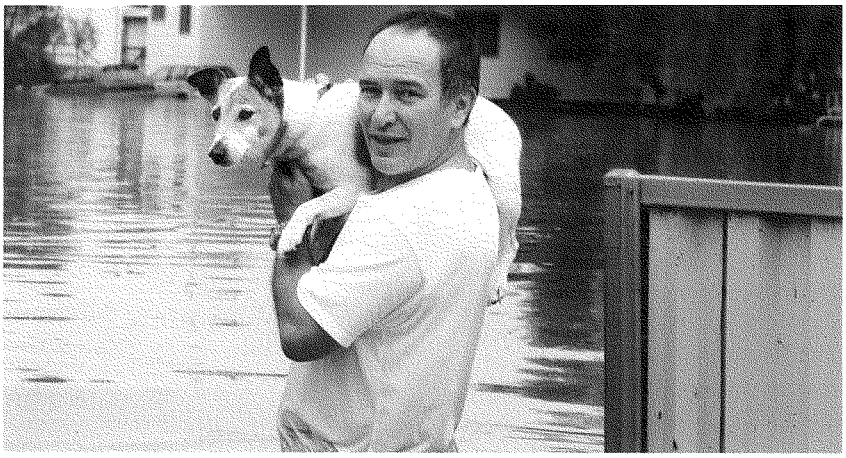


As the population grows and infrastructure expands, increased exposure and vulnerability to these hazards requires risk planning and adaptation for greater resiliency.

Increased weather volatility

In our previous white paper on climate change and increased weather volatility,[1] we outlined how the climate system can change from both natural and man-made influences. It remains unknown exactly how much humans are impacting the natural evolution of climate through land-use changes and greenhouse gas emissions. Projecting those influences into the future with certainty is not yet possible. Our conclusions are that more actionable courses of planning and preparation can be made based on observations of the more recent volatile or extreme weather events, which have been taking place over the last two decades.

Extreme weather is nothing new. Throughout historical record, there have been many occurrences of extreme weather events. Recently, however, some forms of extreme weather have been happening more frequently than natural variability would suggest. It is not known if this volatility will continue into the future, or if this active trend will return to more normal frequencies. Recent research suggests this volatility could be a result of the enhanced warming that has taken place in the Arctic region.[2] A reduction in

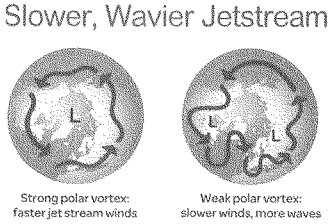


Figure 1
Wavier jet stream

1. Schneider Electric, 2014. Essential Background for Understanding Climate Change and Associated Business Risks 2. Francis, J., Vavrus, S., Tang, Q. 2014. Rapid Arctic Warming and Mid-latitude Weather Patterns: Are They Connected? State of the Climate in 2013. http://journals.ametsoc.org/doi/pdf/10.1175/2014BAMSStateoftheClimate.1

the temperature contrast between the Arctic and the middle latitudes could be weakening the jet stream, causing the resulting atmospheric circulation pattern to buckle and stall out more often. The observed extreme weather events tend to occur more frequently when the jet stream remains stalled in these buckled or wavy configurations for longer periods of time. When weather patterns stall, flooding is more likely to occur as moisture can pool and support repetitive, heavy rains that fall over the same local areas. Wetter or drier-than-normal periods can develop when air masses do not move from a given area. Abnormally cold or warm periods can linger for months, as the jet stream stays locked into the same position for extended periods with little variation. Severe weather will be more common in some of these stalled patterns, and less likely in others. For whatever the cause, the stalled, wavier jet stream behavior leads to more incidents of extreme weather.

Increased exposure and vulnerability

In conjunction with a more volatile weather and climate system, it is important to consider how society is changing as well. Currently, 80 percent of the U.S. population lives in urban areas with high population densities, and demographic trends suggest that urbanization will continue to increase in the future. This means that urban, along with rural-metro areas, are expanding into a larger portion of the landscape, while rural areas with low population density are shrinking. Cities will continue to drive economic growth and wealth, while at the same time concentrating vital infrastructure within highly local areas. Infrastructure elements that are focused within cities include energy, water, wastewater, transportation, public health, banking and finance, telecommunications, food, and information technology. Impacts from a more volatile climate system can therefore have more substantial effects when they occur in these centralized urban areas. Flooding can damage or wash away homes, businesses, and infrastructure, affecting jobs and vital services. At the same time natural flood management is constrained as urbanization reduces the area available for holding floodwaters. Extreme heat, which tends to be more intense in urban cores, can compromise health — especially with an aging population. It can also reduce productivity and impact the functionality of infrastructure. Dry spells, especially ones leading to drought, produce water scarcity issues as cities compete with agriculture, energy production, and recreation for limited water supplies.

About the Author

Jeffry Johnson currently serves as Schneider Electric's chief science officer focusing on long-range and seasonal weather. He holds a Bachelor of Science degree in meteorology from the University of Wisconsin-Madison. In 1993, he became an American Meteorological Society Certified Consulting Meteorologist. Johnson has more than 38 years of experience in weather forecasting for various industries including energy, aviation, and transportation.

Figure 2 shows the current geographic coverage of the expanding urban and metro areas, putting more types of infrastructure into the path of potential weather hazards.[3] Census-defined urban acreage has grown by about four percent per year since 1960, or roughly a million acres per year.[4] Rare weather events, such as an EF5 tornado or an extreme flood, will have an increased probability in the future of tracking through larger population centers, based on urban growth trends alone. Exposure and vulnerability are key factors when evaluating risk. A tropical cyclone can have very different impacts depending on where it makes landfall. High impacts can result even when a non-extreme event occurs where exposure and vulnerability are high, or where several significant events compound problems.

Costs of natural hazards

The Hazards & Vulnerability Research Institute routinely examines county-level hazard data for 18 different natural hazards in the United States, including costs and fatalities that are attributed to these hazards.[5]

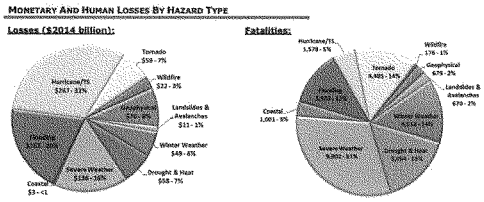


Figure 3

Monetary and human losses by hazard.

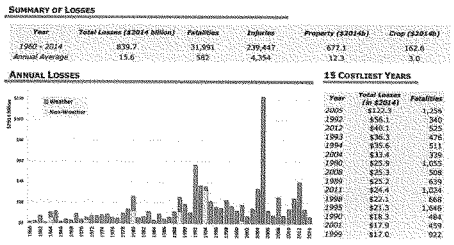


Figure 4

Annual U.S. hazard losses

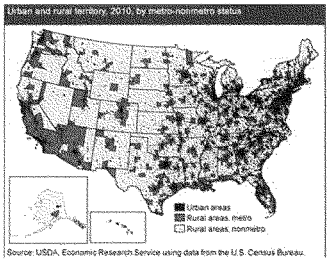


Figure 2

Urban and rural-metro areas.

Figure 3 shows the breakdown of the monetary and human losses for each hazard type during the 55-year period from 1960-2014. Hurricanes and tropical storms have been the most costly type of natural hazards during this period, accounting for 32 percent of the reported losses. Flooding came in second with 20 percent. It is noteworthy that these two hazards, which account for 52 percent of all losses, are related to water, highlighting the significance that water plays in natural disaster costs. Fatalities are more dispersed among the hazards with less focus on the water impacts.

Annual losses from natural disasters can vary from year to year. Figure 4 depicts a plot of the costs from 1960-2014 in 2014 dollars. There has been an upward trend in weather-related losses over the past 20 years. This is likely a combined influence of more active weather, the increased growth and exposure of society, and the increased value of property. Several outlier years show up in this graph, including 1994, which experienced the Northridge earthquake in southern California. In 2004 and 2005, two back-to-back active seasons, there were seven major hurricanes (Category 3 or greater) that made landfalls in the United States, including Hurricane Katrina. In the 11 years following, no major hurricane made a landfall in the United States.

In the past decade there has been a noticeable increase in the number of higher-cost disasters

3. USDA, 2013. Rural Classifications. http://www.ers.usda.gov/topics/rural-economy-population/rural-classifications/what-is-rural.aspx 4. USDA, Trends in Land Use: Two Kinds of Growth. Development at the Urban Fringe and Beyond/AER-803. http://www.ers.usda.gov/media/536705/aer803c_1_.pdf 5. Annual Hazards & Vulnerability Research Institute. 1960-2014 U.S. Hazard Losses. http://hvri.geog.sc.edu/SHELDUS/docs/Summary_1960_2014.pdf

in the United States. Starting in 2008, there have been greater occurrences of billion-dollar events, primarily from severe thunderstorms. Both 2008 and 2011 were very active tornado years. Several destructive storms passed through metropolitan areas, resulting in widespread, heavy damage. There were also several larger-scale windstorm events that generated long-tracked paths of damage through populated areas. Figure 5 illustrates this more active recent period of high-cost storms.[6]

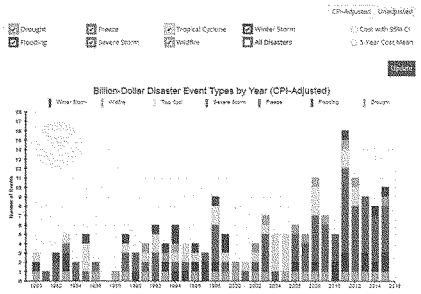


Figure 5

Billion-dollar disasters by type.

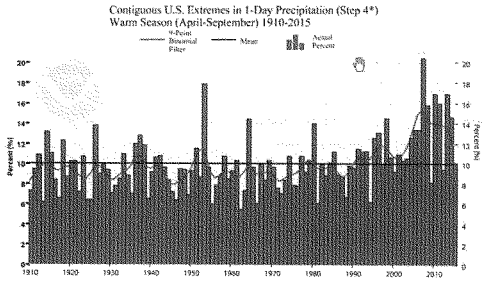


Figure 6

Climate extremes index for one-day heavy precipitation during the warm season.

Extreme weather events and impacts

Considering both the background on historical weather-related costs and the continual growth in population centers and associated infrastructure, it is useful to examine which weather hazards have increased or are more likely to continue to show an increase, due to recent climate and weather volatility. While the more extreme events remain locally rare in nature, it is helpful to explore some of the more common events and impacts that will more likely be encountered, so that actions to limit their disruptions can be evaluated and implemented.

Excessive rainfall and flooding

One of the most noticeable weather events that has shown an increase in recent decades is the greater frequency of extreme rainfall occurrences. Flood losses in the United States have accounted for nearly 20 percent of natural hazard costs since 1960, and this amount could increase in the future if recent trends hold. Heavy one-day rainfall events have shown a greater frequency in the past two decades, especially in the warm season, as shown in Figure 6.[7] The graph represents the percentage of the United States that experienced one-day precipitation amounts in the top 10 percent of historical occurrences. Intense rainfall rates contribute to rapid run-off and flooding, especially in urban areas.

Individuals, businesses, and communities should evaluate the risks associated with extreme rainfall events and consider the impacts that typically occur during and after such incidents. Some of the more commonly observed flood risk scenarios and local impacts include:

Flash floods — extreme rainfall rates with rapid accumulation and runoff. Storm water cannot be removed fast enough to prevent flooded areas. Greater impact occurs with already-saturated soils.

New development in urban areas — more runoff occurs from roofs and pavement; less ground is available for absorption due to the building of structures and increased filling of wetlands.

6. NCDC US Billion Dollar Disasters, http://www.ncdc.noaa.gov/billions/time-series 7. NCDC U.S. Climate Extremes Index. http://www.ncdc.noaa.gov/extremes/cei/graph/4/04-09

Dam/levee failures — there are 74,000 dams in the United States with one-third posing a risk to life and property if they fail. Excessive rainfall, both short-term and over many days, can lead to breaches.

Mudslides, rock, and debris flows — hillsides become unstable when they are saturated by heavy rainfall. Removal of vegetation nearby may contribute to greater soil saturation. Burn scars are more susceptible. (See images in Figure 7.)

Tropical storms and hurricanes — extensive, heavy rainfall over one to three days can saturate the soil over a large area. Storm surges near the coast are the most destructive impact as a tropical storm or hurricane moves onshore.

Figure 7

Mudslide and road washouts from heavy rainfall events in Minnesota (June 2014).

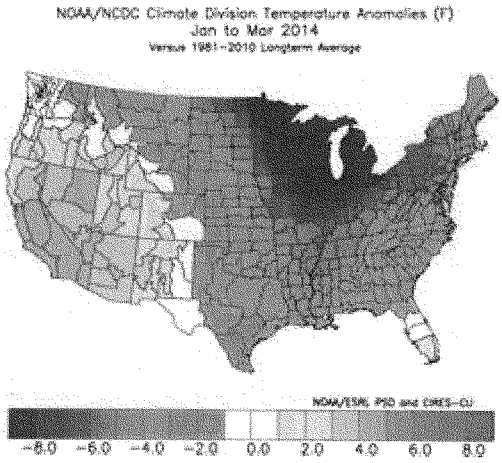


Figure 8

Abnormally cold winter (January-March 2014).

River and lake flooding — heavy rainfall over a period of time raises lake and river levels, with water expanding onto shorelines and into floodplains. May also occur with ice jams.

Heavy rain on frozen ground or melting snowpack — frozen ground does not absorb melting snow or falling rain, leading to flash flooding, as well as river and stream floods. Heavy rainfall during this scenario produces greater impacts.

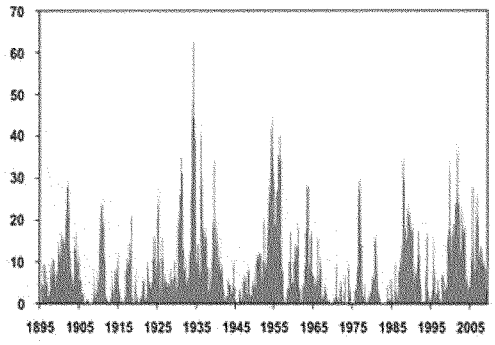
Extended periods of abnormal temperatures

It is not unusual for the weather to be colder or warmer than average for short periods of time (days to weeks). Indeed, it is this variation that is averaged over time to define what is normal for a given area. In recent years, there has been a greater tendency for abnormally warm or cold periods to set up in an area and persist for long durations of time (months to seasons). It is the frequency and persistence of these long-duration events that has become more common recently.

At times, the intensity of the warmth or coldness itself during a persistent event can become more extreme. These anomalous temperature patterns tend to develop when the jet stream buckles and stalls, keeping cold or warm locked into areas for extended periods of time. A recent example of an extended period was the winter of 2013-2014, when cold air remained anchored in the Central and Eastern United States. Temperatures were more than eight degrees colder than normal during January through March 2014 (Figure 8), which is quite extreme for a 90-day period. Europe, Asia, and North America have seen numerous examples of such patterns, both cold and warm, in the last decade. More are likely to occur as long as the slower, more undulating jet stream persists. Energy demands increase during these events, raising costs and stretching energy supplies. Retail sales, especially auto, restaurants, and entertainment venues are hurt as consumers stay at home more often. Home construction can be delayed during extreme cold. Logistical and travel networks can be disrupted, especially when wintry precipitation covers wider areas, resulting in more canceled flights and delayed deliveries.

Drought, water supply, and wildfires

Drought has resulted in significant long-term economic costs to society. In the United States, there have been a growing number of billion-dollar droughts over the last 30 years, with extreme droughts in the Southeast, the Southern Plains, the Midwest, and California over the past decade. Drought is a natural part of the climate system, varying in intensity, duration, size, and location from year to year. It is common that some portion of the United States will experience drought each year, with a long-term average of 14 percent of the country being impacted annually. Figure 9 is a timeline depicting what percentage of the United States was in drought each year from 1895 through 2010. Massive droughts occurred in the 1930s and 1950s, with vast areas involved. In much the same way as abnormal temperature patterns set up with stalled and wavier jet stream patterns, droughts develop when the jet stream steers around a region for many months, decreasing the chances for precipitation. Droughts are slowly developing disasters that can expand outward with time and encompass more territory. Irrigation and the planting of more drought-tolerant crops help to lessen the impacts of drought. Crop losses can result in shortages that push up food prices and sometimes lead to the culling of livestock herds by ranchers as water and feed supplies are reduced.



Based on data from the National Climatic Data Center/NOAA

Figure 9

Percent of the United States in drought.

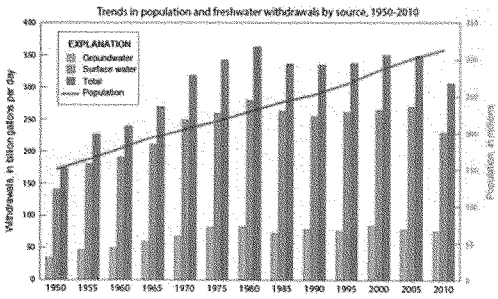


Figure 10

Water usage.

Drought is likely to be a significant threat in the future, even in the absence of any upward trends in intensity and coverage. Rainfall deficits over a long period of time put strain on available water resources. Growth in water usage will escalate as the population increases and new water utilizations, such as hydraulic fracturing, increase demands. Figure 10 shows the trends in surface-water, groundwater, and total-water withdrawals for the United States from 1950 to 2010.[8] The relative amounts of surface and groundwater withdrawals have remained fairly constant since 1985, even though the population has grown, along with irrigation and industrial growth. This slow-down in use is likely due to water conservation practices and efficiencies put in place since that time. About three-fourths of the water used in the United States comes from surface water.

Figure 11 allocates the primary users of the water supply. Water use for electricity production, the largest user, increased almost 500 percent from 1950 to 1980, but has leveled off and even decreased since then. Irrigation use increased by about 43 percent as it takes more water to grow food for an increased population and global markets, but it too has been reduced in recent years. The purple public-supply boxes, which represent local water supplies delivered to homes and businesses, has shown steady slow growth and may grow further due to ever-increasing population demands.

8. USGS, 2010. Trends in Water Use in the United States, 1950 to 2010. water.usgs.gov/watuse/wutrends.html

Abnormally dry weather patterns and droughts can have a greater impact when they occur in areas where the water supply is more limited. Figure 12 illustrates the concept of a water supply stress index. The index shows areas where watersheds are considered stressed when water demand from power plants, agriculture, and municipalities exceed available supplies.[9] An index value of 0.4 (40 percent) or greater is considered stressed. In addition to much of the arid West, a number of local or regionally stressed areas are also found in the eastern part of the United States. California and the inter-mountain western United States get most of their annual rainfall

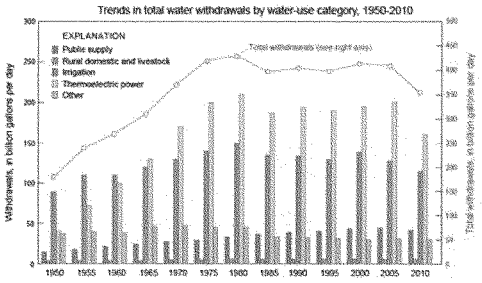


Figure 11

Water withdrawals by category.

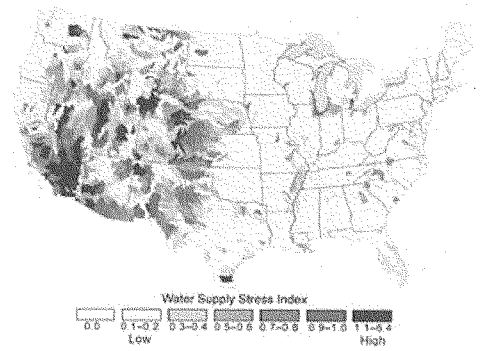


Figure 12

Water stress index (figure source: Averyt et al. 201120).

during the winter months, so an extreme drought of just three to four months duration can have an enormous impact. Drought in the future will put added strain on water resources, requiring greater sharing and coordination among various consumers, especially in areas of more limited supply.

Extreme dryness or drought can also lead to enhanced wildfire conditions. Wildfires have always been a part of nature, with a tendency to be more common during the hot and dry season. Lightning initiates many fires in the more arid western United States, but humans are a contributor as well, whether by accident or arson. Wildfire activity in the western United States increased substantially in the late 20th century with the increase primarily caused by higher temperatures and earlier snowmelt. Similarly, increases in wildfire activity in Alaska from 1950 to 2003 have been linked to increased temperatures. The principal economic costs of wildfires include timber losses, property destruction, fire suppression efforts, and losses to the tourism sector. Encroachment of urban development into areas that are susceptible to wildfires increases the risks and costs when fires break out. Figure 13 depicts how fire losses in California have increased significantly in recent decades, as the urban-wildland interface increased from greater development. Over five million homes in California are located within the urban-wildland interface.[10] Vulnerabilities for landslides increase in areas with thinned vegetation from droughts or wildfires.[11]

Managing risks

Disaster risk planning and management, in light of recent weather and climate volatility, are sound approaches to help prepare for and reduce costs associated with the increased hazard threats. Recent changes in these threats might result in new vulnerabilities that were not previously encountered or understood. Many of the more acute weather events are unpredictable and unevenly distributed across space and time, so knowledge of exactly when and where they might occur is limited. Increasing

9. UCS, 2011. Freshwater Use by U.S. Power Plants. http://www.ucsusa.org/assets/documents/clean_energy/ew3/ew3-freshwater-use-by-us-power-plants.pdf
10. Environmental Research Letters, 2009. Urban-wildland fires: How California and other regions of the US can learn from Australia. http://cnr.berkeley.edu/stephens-lab/Publications/Stephens%20et%20al.%202009%20CA%20AU%20UWI%20En%20Res%20Let.pdf 11. USDA, 2012. Effects of Climatic Variability and Change on Forest Ecosystems. http://www.usda.gov/oce/climate_change/effects_2012/FS_Climate1114%20opt.pdf

resilience to these changing risks can be accomplished by reducing exposure, lessening vulnerability, or transferring or sharing the risks through insurance. Risk management is often governed by the probability of an event multiplied by its consequence. For example, an EF5 tornado is a rare event, but one that moves through a metropolitan area can have devastating results. Reducing exposure and vulnerability to these events reduces the risk, but may come with great cost or political resistance. Risk transfer is a method of insuring against potential losses, which may be a more economical way to guard against a low-probability occurrence.

Various business sectors and local populations have begun to document their experiences with the changing climate system, particularly with extreme weather events.[12] Some of this self-generated knowledge may help facilitate discussions on proactive adaptation strategies. It might also help discover some existing capacity to adapt or it may reveal important current shortcomings. Some of this information on best practices can aid the development of vulnerability and adaptation assessments. The following section highlights a number of the observed and expected impacts on several sectors of business and infrastructure, along with suggested methods for adapting to the risks.

Energy

Sector-based impacts and practices for increasing resilience

Energy — recent climate volatility has raised the awareness of its impacts on the energy industry. Severe droughts, such as those seen in 2010, 2012, and 2014, can affect the supply of cooling water to power plants, disrupting the supply of power.[13] Abnormal and persistent temperature regimes can strain fuel supplies and impact earnings. Flooding of infrastructure, especially along coastal areas, can take those facilities offline, as well as require costly repairs. Insurers have recently started to factor in climate change in their insurance cost calculations. Insurance affordability and availability could potentially slow the growth of the energy industry and shift more of the costs to users.

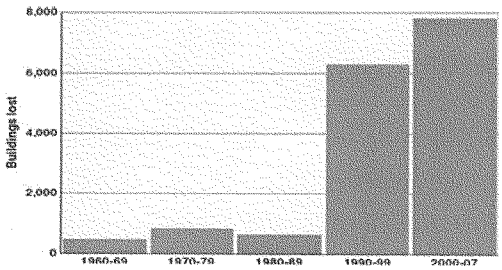


Figure 13

Number of building losses from fires in California along the urban-wildland interface (1960-2007).

The following list includes some ways that the energy sector is assessing the increased weather risks with methods to help manage those concerns:

More extreme rainfall:

- Flooding of infrastructure, especially near waterways and floodplains can take those facilities offline, as well as require costly repairs.
  - Harden plants and substations to reduce the threat of flooding in susceptible areas to help decrease this risk
  - Elevate platforms used to store materials
  - Preserve and improve open space in floodplains
  - Utilize short-term weather forecasts
  - Install weather stations to monitor events in real-time
- Higher volumes of precipitation can saturate soils and weaken support for electric distribution poles, making them less study during strong winds.
  - Inspect distribution infrastructure
  - Examine areas where mudslides or erosion could occur

Extended periods of abnormal warmth or cold:

- Extreme cold can stress energy supplies and infrastructure. Conversely, earnings can be affected significantly during the winter heating season if weather is abnormally warm and energy usage is reduced. An increase in extreme heat will drive up demand for air conditioning, requiring greater electric loads and peak generating capacity.
  - Use a longer time horizon for estimating extreme or peak values
  - Utilize longer-term seasonal weather forecasts
  - Insulate equipment for temperature extremes

12. CDP, 2014. Major public companies describe climate-related risks and costs. https://www.cdp.net/CDPResults/review-2011-2013-USA-disclosures.pdf
13. Pulwarty, R.S. 2013, Testimony of Dr. Roger S. Pulwarty on Drought and the Effect on Energy and Water Management Decisions, U.S. Senate Committee on Energy and Natural Resources. http://www.legislative.noaa.gov/Testimony/Pulwarty042513.pdf

- More extreme temperature patterns could increase the threat for stronger coastal storms that produce high winds and waves. These may curtail coastal and offshore oil and gas production, temporarily driving up prices and producing shortages. Coastal storm surges could also flood vulnerable infrastructure.
  - Upgrade flood protection
  - Use on weather consultations for pre-storm planning

Extreme dryness or drought:

- Drought, especially severe droughts, reduces the supply of cooling water to power plants and increases costs for water-use rights and permitting. Reduced hydroelectric power resources require shifting to more expensive power sources.
  - Bank water in reservoirs during off-peak seasons
  - Use seasonal weather outlooks and consultations for planning
- Water usage, which will continue to grow with an expanding population, will strain existing resources in the future with increased competition among sectors. Drought in water-stressed areas could curtail hydraulic fracturing operations.
  - May need to rely on more expensive groundwater sources
- In areas with increased wildfire risks, overhead power lines and substations can be damaged when a fire moves through.
  - Forest management (thin and remove debris near streams)

Transportation

Transportation — transportation infrastructure is especially vulnerable to precipitation extremes. Flooding produces a significant impact on infrastructure, including high water that occurs with flash floods, river and stream flooding, and storm surges. Floods can damage infrastructure, including roads, bridges, culverts, and even railways, airports, and coastal ports. Rushing water can wash out soil that surrounds bridge foundations, weakening the support function. Mudslides occur when heavy rain destabilizes hillsides, which can quickly close roads or cut-off communities. Road washouts, mudslides, and flooded roads can delay deliveries and inhibit employees' ability to commute to workplaces. River flooding that follows heavy rain events or low water levels during drought conditions, can restrict river transportation, disrupting barge traffic. Flash floods can be costly to rail transportation, which is primarily impacted by bridge washouts.

Extreme temperatures can also impact transportation infrastructure. They cause expansion and increased movement of concrete joints, protective cladding, coatings, and sealants on bridges and airport infrastructure, and stress the steel in bridges. Extreme heat along with rapid temperature changes can damage rail tracks as the track buckles.[14]

The following list includes some ways that the transportation sector is assessing increased weather risks with methods to help manage those concerns:

More extreme rainfall:

- Flooding of infrastructure includes roadway flooding, damage or destruction to bridges, pavement washouts, mudslides, subway flooding, airport flooding, and curtailment of barge operations.
  - Upgrade stormwater drainage facilities
  - Protect existing infrastructure, such as bridge foundations from floodwaters
  - Preserve and improve open space in floodplains
  - Reinforce slopes
  - Relocate vulnerable routes
  - Increase inspections and maintenance of levee and drainage systems, including riverbeds
  - Enhance emergency response to flooding
  - Install weather stations and early warning systems to monitor events and assets

Extended periods of abnormal warmth or cold:

- Extreme heat can cause rail tracks to buckle and kink, disrupting rail service until the track is replaced. High temperatures can cause concrete pavement to buckle or explode, especially when recent rainfall has seeped into its cracks.
  - Increase inspection of track during high heat and large temperature swings

Extreme dryness or drought:

- Severe droughts reduce the water flow on inland water systems, which can disrupt barge traffic.
  - Shift product shipments to train and truck delivery
  - Use seasonal weather outlooks and consultations for planning

14. USDOT, 2012. U.S. Department of Transportation Climate Adaptation Plan. Ensuring Transportation Infrastructure and System Resilience. http://www.dot.gov/sites/dot.dev/files/docs/DOT%20Adaptation%20Plan.pdf

Municipalities

Municipalities — the United States is highly urbanized with approximately 80 percent of the population living in metropolitan areas. Aging and concentrated infrastructure in these urban areas is at an increasingly higher risk from extreme weather events. Examples of urban infrastructure elements that are at risk include energy, water, wastewater, transportation, public health, banking and finance, telecommunication, food, and information technology. Disruptions in essential services can have large impacts because many of these services are reliant upon each other.

High impact events for municipalities include, extreme rainfall leading to flooding, storm surge flooding in coastal locations, severe storms that cause property damage and power outages, snow and ice storms that snarl transportation and trigger power outages, periods of extended dryness leading to water shortages, and high heat and humidity leading to health issues. Drought increases fire risks in the urban-wildland interface.

Land management is an important tool to help offset some impacts, especially flooding. This includes land use planning, zoning, conservation zones, buffer zones, or land acquisition. Often it is difficult for local jurisdictions to implement such management measures due to political and economic pressures for new development, or the perception of shifting the problems onto others.[15]

Heavy precipitation events are strongly correlated with the outbreak of waterborne illnesses in the United States, primarily from water supply contamination and sewage treatment plant overflows. Fifty-one percent of waterborne disease outbreaks were preceded by an extreme precipitation event.

The following list includes some ways that municipalities are assessing the increased weather risks with methods to manage those concerns:

More extreme rainfall:

- Flooding of infrastructure includes roadway flooding, damage or destruction to bridges, pavement washouts, mudslides, and subway and airport flooding. Sanitary sewer backups occur when stormwater overwhelms that system.
  - Upgrade stormwater drainage facilities
  - Reduce infiltration of rainwater into the sanitary sewer system
  - Protect existing infrastructure, such as bridge foundations, from floodwaters
  - Preserve and improve open space in floodplains through land-use planning and zoning
  - Create conservation or buffer zones
  - Reinforce slopes
  - Relocation of vulnerable routes
  - Construct or enhance levees in areas at risk from storm surges
  - Increase inspections and maintenance of levee and drainage systems, including streams and riverbeds
  - Enhance emergency response to flooding
  - Monitor the water supply for disease potential
  - Install weather stations and early warning systems to monitor events and assets

Extended periods of abnormal warmth or cold:

- Extreme cold or heat can stress the urban population. The elderly are particularly sensitive to heat waves. Some may be physically frail, have limited financial resources, and/or live in relative isolation in their apartments. They may not have adequate cooling (or heating), or may be unable to temporarily relocate to cooling stations. Extended periods of heat can be focused in cities, which often retain more heat at night.
  - Develop plans for public health and welfare during heat waves, including cooling centers

Extreme dryness or drought:

- Severe droughts reduce the amount of available water supply to cities, and increase demand for watering and recreation.
  - Proactively institute water restrictions
  - Use low-water landscape techniques

Agriculture

Agriculture — agriculture experiences a number of the impacts from a more volatile weather and climate system. Farmers have been on the front-lines of these changes and have taken measures to help offset their risk. Commodities that are produced by this industry will be vulnerable to direct impacts, such as changes in crop and livestock development and yield, as well as indirect impacts from pests and pathogens that emerge in some volatile patterns.

15. Jennings, T.L. 2011, Transcending the Adaptation/Mitigation Climate Change Science Policy Debate: Unmasking Assumptions about Adaptation and Resilience. http://journals.ametsoc.org/doi/pdf/10.1175/WCAS-D-11-00056.1

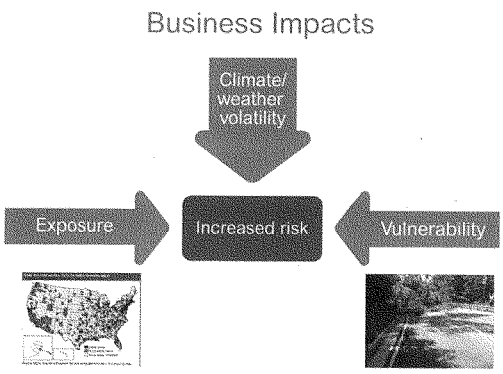
The following list includes some ways that the agriculture industry is assessing the increased weather risks with methods to better manage those concerns:

More extreme rainfall:

- Flooding — extreme rainfall, beyond the direct destruction of property, has important negative impacts on agriculture. Heavy precipitation and field flooding of agricultural systems delays spring planting, increases soil compaction, and causes crop losses through anoxia and root diseases. Flooding also increases soil erosion. The industry has installed drain tiles to increase dispersal of excess water from fields, but this also contributes to higher river levels and reduced groundwater infiltration.
  - Install drain tiles to remove water from fields
  - Preserve wetlands and other lowlands
  - Minimize off-farm flow of nutrients and pesticides with buffer zones

Extended periods of abnormal warmth or cold:

- Extreme cold or heat, along with abnormal and lengthy temperature anomalies, has impacted crops in recent years. Cold and wet springs can delay field preparation and planting. Extended heat, especially when combined with drought, can reduce crop yields or decimate the entire season's product.
  - Plant more heat tolerant crops
  - Increase use of temperature-controlled housing for livestock
  - Increase use of pesticides
  - Utilize seasonal weather forecasts for strategic planting decisions.



Extreme dryness or drought:

- Severe droughts — excluding 2003, from 2000 to 2010, crop losses accounted for nearly all of the direct damages resulting from droughts in the United States. Severe droughts in the past decade have affected large areas of the Southeast, Midwest, South, and West. Farmers have increased their installation of center pivot irrigation systems to help offset both short-term dryness and longer term drought.[16] Drought can also force livestock herds to be culled due to the high cost or unavailability of water or the reduced productivity of rangeland.[17]
  - Install center pivot irrigation systems
  - Use precision irrigation systems
  - Plant more drought tolerant crops

Conclusion

Recent weather and climate variations have produced a large number of outlier events. These events have been impactful to a number of locations around the United States. While some of these events have been unusual in their severity, societies increasing exposure and vulnerability to these events are resulting in greater disruptions. Extreme rainfall, drought, and extended periods of abnormal warmth or cold are the most frequent outlier weather events taking place. Flooding events have historically been the most costly and their increased frequency suggests that a priority be placed in that area. Each of these more common outlier hazards can impact individuals, businesses, and government agencies. Awareness of the hazards and their impacts can help to formulate plans and enable actions that may help offset the risks associated with these events.

16. USDA, 2012, Climate Change and Agriculture in the United States: Effects and Adaptation. http://www.usda.gov/oce/climate_change/effects_2012/CC%20and%20Agriculture%20Report%20(02-04-2013)b.pdf 17. National Drought Mitigation Center, Checklist of Historical, Current and Potential Drought Impacts. http://drought.unl.edu/portals/0/docs/checklist.pdf

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Chairman BRIDENSTINE. Thank you, Mr. Block.
Dr. Jacobs, you're recognized for three minutes.

TESTIMONY OF DR. NEIL JACOBS,
CHIEF SCIENTIST,
PANASONIC WEATHER SOLUTIONS, PANASONIC

Dr. JACOBS. Good morning, Chairman Bridenstine, Ranking Member Bonamici, members of the Subcommittee. My name is Neil Jacobs, and I serve as Chief Scientist for Panasonic Weather Solutions. I am honored to be invited to participate in today's hearing.

Panasonic has a great public-private partnership to provide its TAMDAR data to NOAA through the National Mesonet Program, which is an example of a successful and sustainable business model for data acquisition. Panasonic is very pleased to continue our long-term relationship with NOAA to improve the quality of weather forecasting. The distinct advantages of our TAMDAR data will enhance the National Weather Service's core mission: the protection of life and property.

TAMDAR provides real-time global observations of wind, temperature and moisture, its spatial and temporal resolutions greater than both radiosondes and ACARS. TAMDAR-equipped aircraft and UAVs also report real-time icing and turbulence, which are routinely used by the NTSB for accident investigations. The SATCOM transmission doubles as a real-time back channel communication and flight tracking system.

Dr. Louis Uccellini, Director of NOAA's National Weather Service, said the National Weather Service has long recognized the utility of TAMDAR data for analysis and numerical forecast models, and I am pleased about this path forward to incorporate these data in our day-to-day operations. Dr. Curtis Marshall of the National Weather Service has said the provision of this unique TAMDAR data set continues to steer the National Mesonet Program in a direction consistent with the National Academy of Science's Network of Networks vision of a broad range of non-federal data to improve situational awareness at the National Weather Service forecast offices and to enhance our high-resolution modeling capabilities.

Panasonic also runs a suite of models from rapid cycling regional models to our own global model including an 80-member ensemble. These models were developed through longstanding collaborative partnerships with both NCAR and several universities. Panasonic is the only private entity in the world with a custom-developed end-to-end operational global weather modeling platform initialized from raw observations. Panasonic has worked cooperatively with federal agencies by providing TAMDAR data to NOAA and the FAA and at many times at no cost.

While we are a commercial company responsible to our shareholders, we also have another responsibility: to help share our technological expertise with meteorological agencies around the world.

In closing, I would like to call the Subcommittee's attention to NOAA document NAO–216112, Policy on Partnerships and the Provision of Environmental Information. This policy is intended to strengthen the partnerships between public, private, and academic sectors to provide the Nation with the highest quality environmental information. The partnership agreement was approved in

2006 by then-NOAA Administrator Dr. Conrad Lautenbacher. It was developed in response to recommendations from the National Academy of Science and the Fair Weather report. I recommend the Subcommittee work closely with NOAA, the American Meteorological Society, and America's weather enterprise on any revisions to this important agreement.

Mr. Chairman and members of the Subcommittee, thank you again for inviting me to participate today. I'm happy to take your questions.

[The prepared statement of Dr. Jacobs follows:]

Statement of

Neil A. Jacobs. Ph.D.
Chief Atmospheric Scientist - Panasonic Weather Solutions
Panasonic Avionics Corporation

Before the

Subcommittee on Environment
Science, Space, and Technology Committee
U.S. House of Representatives

Hearing on

"Private Sector Weather Forecasting:
Assessing Products and Technologies"

June 8, 2016

Good morning, Chairman Bridenstine, Ranking Member Bonamici, and Members of the Subcommittee. My name is Neil Jacobs, and I serve as the Chief Atmospheric Scientist for Panasonic Weather Solutions, a division of Panasonic Avionics Corporation, a global company operating in the United States with employees and offices in several states. I am honored to be invited to participate in today's hearing to examine the advancement and progress that has been made by the private sector in weather forecasting.

In 2003, the National Research Council reported in *Fair Weather: Effective Partnerships in Weather and Climate Services*, otherwise known as *The Fair Weather Report*, "that the commercial weather industry now has the capability to provide many of the products and services that were once the exclusive domain of the federal government..." [1]

Panasonic has a great public-private partnership to provide its TAMDAR Data to the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service through the National Mesonet Program, which is an example of a successful and sustainable business model for atmospheric data acquisition.

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[1] Fair Weather: Effective Partnerships in Weather and Climate Services, Chapter Three, Page 43.

Panasonic is very pleased to continue our long-term relationship with NOAA to improve the quality of weather forecasting. The distinct advantages of our TAMDAR Data from aviation-based observations will enhance the National Weather Service's core mission "the protection of life and property."[2]

TAMDAR, which stands for Tropospheric Airborne Meteorological Data Reporting, provides real-time observations of wind, temperature, moisture, pressure, icing, and turbulence at spatial and temporal resolutions greater than both radiosondes and traditional ACARS (Aircraft Communications Addressing and Reporting System) data from a global network of regional airlines via the Iridium satellite network or Panasonic's high-throughput satellite system. Inherent within this system is real-time backchannel communication and flight tracking.

Last year, Dr. Louis Uccellini, director of NOAA's National Weather Service said, "The National Weather Service has long recognized the utility of TAMDAR data for analysis and numerical forecast models, and I'm

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[2] National Weather Service, About NOAA's NWS, Our Mission, http://www.weather.gov/about

pleased about this path forward to incorporate these data in our day-to-day operations."[3]

Dr. Curtis Marshall, also at the National Weather Service has said, "The provision of this unique TAMDAR dataset continues to steer the National Mesonet Program in a direction consistent with the National Academy of Science's 'Network of Networks' vision of a broad range of non-federal data to improve situational awareness at National Weather Service forecast offices and to enhance our high-resolution modeling capabilities."[4]

Observations from the TAMDAR-equipped aircraft and US Air Force UAVs also include real-time icing and turbulence reports, which are vital to assist commercial, general and military aviation. TAMDAR icing data provides the first high-volume, objective icing reports available to the aviation industry.

Meteorologists at the National Transportation Safety Board (NTSB) routinely use TAMDAR data as part of their accident investigations,

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[3] Wings Magazine, Panasonic, NOAA sign deal for hi-res weather data, November 2015

[4] Wings Magazine, Panasonic, NOAA sign deal for hi-res weather data, November 2015

including high-profile incidents such as the Colgan Air flight 3407, which crashed near Buffalo, New York claiming the lives of 45 passengers and 4 crew (February 12, 2009), [5] and the de Havilland Otter, which crashed near Dillingham, Alaska, claiming the lives of 5 of the 9 passengers including, Alaska's late U. S. Senator Ted Stevens (August 9, 2010).[6]

In addition to collecting weather data from aircraft, Panasonic also runs a suite of numerical forecast guidance from rapid-cycling regional and tropical models to our very own global model, including an 80 member global ensemble.

These weather models were developed through long-standing collaborative partnerships with the National Center for Atmospheric Research (NCAR) and several universities. The forecast models use all publically available global weather observations, as well as Panasonic's proprietary TAMDAR data.

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[5] Colgan Air Submission to the NTSB, December 2009
http://www.airsafe.com/events/airlines/colgan-ntsb-submit.pdf

[6] NTSB Aircraft Accident Report, May 24, 2011
http://www.ntsb.gov/investigations/AccidentReports/Reports/AAR1103.pdf

Panasonic Weather Solutions is the *only* private entity in the world with a custom-developed, end-to-end global weather-modeling platform initialized from raw observations, and completely independent from NWS-produced global model data.

Since its founding in 1998, Panasonic Weather Solutions (formerly AirDat) has worked cooperatively with federal agencies by providing its TAMDAR data to NOAA and the FAA, and -- many times at no cost. While we are a commercial company responsible to our shareholders -- we at Panasonic also have another responsibility – to help share our technological expertise with national meteorological agencies around the world.

In closing I would like to call the subcommittee's attention to NOAA Administrative Officer Document: NAO 216-112: Policy on Partnerships in the Provision of Environmental Information. This policy is intended to strengthen the partnership among government, academia and the private sector to provide the nation with the highest quality environmental information. The NOAA Partnership Agreement was approved in 2006 by then NOAA Administrator Dr. Conrad C. Lautenbacher, Jr., VADM USN

(ret.). It was developed in response to recommendations from the National Academy of Science and the publication of *The Fair Weather Report*. I recommend that the Subcommittee work closely with NOAA and America's Weather Industry on any revisions to this important agreement.

Mr. Chairman and Members of the Subcommittee, thank you again for inviting me to participate today. I would be pleased to answer any questions you may have about Panasonic Weather Solutions.

Additional Background Information

The Origins of TAMDAR

In response to a government aviation safety initiative in the early 2000's, NASA, in partnership with the FAA, NOAA, and private industry, sponsored the early development and evaluation of a proprietary multi-function in-situ atmospheric sensor for aircraft. The predecessor to Panasonic Weather Solutions, AirDat (formerly ODS of Rapid City, SD), was formed in 2003 to develop and deploy the Tropospheric Airborne Meteorological Data Reporting (TAMDAR) system based on requirements provided by the Global Systems Division (GSD) of NOAA's Earth System Research Laboratory, the FAA, and the World Meteorological Organization (WMO).

The TAMDAR sensor was originally deployed in December 2004 on a fleet of 63 aircraft operated by Mesaba Airlines in the Great Lakes region of the United States as a part of the NASA-sponsored Great Lakes Fleet Experiment (GLFE). Over the last twelve years, equipage of the sensors has expanded beyond the continental US (CONUS) to include airlines flying over Alaska, Caribbean, Mexico, Central America, Europe, and Asia. The

TAMDAR system has been in continuous operation since initial deployment in December 2004.

What is TAMDAR?

TAMDAR observations include temperature, pressure, winds aloft, relative humidity (RH), icing and turbulence that are critical to both aviation safety and the operational efficiency of the U.S. National Airspace System (NAS) and other world airspace management systems as well as other weather-dependent operational environments such as maritime, defense and energy. Additionally, each observation includes GPS-derived horizontal and vertical (altitude) coordinates, as well as a time stamp to the nearest second. With a continuous stream of observations, TAMDAR provides higher spatial and temporal resolution compared to the Radiosonde (RAOB) network, as well as better geographic coverage, and a more complete data set than sent over Aircraft Communication Addressing and Reporting System (ACARS), which lacks RH, icing, and turbulence.

Upper-air observing systems are normally subject to latency based on the communication networks used and quality assurance protocol. TAMDAR observations are typically received, processed, quality controlled, and available for distribution or model assimilation in less than one minute

from the sampling time. The sensor requires no flight crew involvement; it operates automatically and sampling rates and calibration constants can be adjusted by remote command from a US-based operations center. TAMDAR sensors continuously transmit atmospheric observations via a global satellite network in real-time as the aircraft climbs, cruises, and descends.

The system is normally installed on fixed-wing airframes ranging from small, unmanned aerial systems (UAS) to long-range wide-body aircraft. Emphasis has been placed on equipping regional carriers as these flights tend to (i) fly into more remote and diverse locations and (ii) be of shorter duration thereby producing more daily vertical profiles while remaining in the boundary layer for longer durations.

Panasonic Forecast Models

Third-party studies have been conducted by NOAA-GSD (Global Systems Division), the National Center for Atmospheric Research (NCAR), and various universities and government agencies to verify the accuracy of TAMDAR data against that of weather balloons and aircraft test instrumentation, as well as quantifying the TAMDAR-related impacts on Numerical Weather Prediction. Ongoing data denial experiments show that

the inclusion of TAMDAR data can significantly improve forecast model accuracy with the greatest gains realized during more dynamic and severe weather events.

Upper-air observations are the single most important data set driving a forecast model. Fine-scale regional forecast accuracy is dependent on a representation of the mid and upper-level atmospheric flow, moisture, and wave patterns. If these features are properly analyzed during the model initialization period, then an accurate forecast will ensue. TAMDAR data has been shown to increase forecast accuracy over the U.S. on the order of 30- to 50-percent for a monthly average, even for 3D-Var (GSI) models.

The FAA funded a four-year TAMDAR impact study that was concluded in January 2009. The study was conducted by the Global Systems Division (GSD) of NOAA under an FAA contract to ascertain the potential benefits of including TAMDAR data to the 3D-Var Rapid Update Cycle (RUC) model, which was the current operational aviation-centric model run by National Centers for Environmental Prediction (NCEP). Two parallel versions of the model were run with the control withholding the TAMDAR data. The results of this study concluded that significant gains in forecast skill were achieved with the inclusion of the data despite using 3D-Var assimilation methods. The reduction in 30-day running mean RMS error

averaged throughout the CONUS domain within the boundary layer for model state variables were:

- Up to 50% reduction in RH error
- 35% reduction in temperature error
- 15% reduction in wind error

This study was conducted using a 3D-Var model on a 13 km horizontal grid. Likewise, the nature of the 30-day mean statistics dilutes the actual impact provided by TAMDAR's higher resolution data during critical weather events. The forecast skill gain during dynamic events is typically much greater than what is expressed in a CONUS-wide monthly average. In other words, the increase in model accuracy is greatest during dynamic weather events where air traffic and other operational impacts are greatest.

The Panasonic Weather Solutions RT-FDDA-WRF forecast runs on a North America domain with 4 km grid spacing and can include multiple nested 1 km domains. A four-year collaborative study with NCAR using the same data as in the studies referenced above has shown that the FDDA/4D-Var assimilation methodology can nearly double the improvement in forecast skill over an identical model running a 3D-Var configuration. Results from this study are summarized below using the same 30-day

running mean verification statistics as employed by NOAA. TAMDAR impact using FDDA/4D-Var resulted in:

- Reduction in humidity forecast error of 74%
- Reduction in temperature forecast error of 58%
- Reduction in wind forecast error of 63%

Forecast skill, like the example presented above, is made possible by having (i) an asynoptic in-situ observing system like TAMDAR that streams continuous real-time observations to (ii) a forecast model (deterministic or probabilistic) that has the ability to assimilate asynoptic data in four dimensions.

Weather Products for the Aviation Industry

Icing Data

In addition to our forecasting and modeling expertise, Panasonic Weather Solutions also excels in the collection of Icing and Turbulence Data, which is vital to assist commercial, general and military aviation. TAMDAR icing data provides the first high volume, objective icing data available to the airline industry. Ice reporting is normally available via pilot reports (PIREPs); while helpful, these subjective reports do not provide objective accuracy and density. High-density, real-time

TAMDAR icing reports provide accurate spatial and temporal distribution of icing hazards, as well as real-time observations where icing is not occurring. The icing data can be made available in raw observation form, or it can be used to improve icing potential model forecasts.

Turbulence Observations

The TAMDAR sensor provides objective, high-resolution eddy dissipation rate (EDR) turbulence observations. These data are collected for both median and peak turbulence measurements and are capable of being sorted on a finer (7-point) scale than current subjective pilot reports (PIREPs), which are reported as light, moderate, or severe. The EDR turbulence algorithm is aircraft-configuration and flight-condition independent, thus it does not depend on the type of plane, nor does it depend on load and flight capacity. This high-density real-time in-situ turbulence data can be used to alter flight arrival and departure routes. It also can be assimilated into models to improve predictions of threatening turbulence conditions, as well as being used as a verification tool for longer-range numerical weather prediction (NWP) based turbulence forecasts. As

with the icing observations, potential utility of this data in air traffic control decision-making for avoidance and mitigation of severe turbulence encounters can be significant.

Panasonic's Technological Advancement & Progress

Panasonic Weather Solutions announced in April 2016 that its Tropical 4D weather forecasting service would be available for the start of the 2016 tropical season. Tropical 4D will provide partners with detailed tropical system forecasting information, including Panasonic's proprietary tropical cyclone forecast tracks, for multiple regions around the globe. Tropical 4D is powered by Panasonics Global 4D Weather, the commercial industry-leading global weather prediction platform, which takes full advantage of Panasonic's exclusive atmospheric datasets including TAMDAR.

Panasonic Weather Solutions is the *only* private entity in the world with a custom-developed, end-to-end global weather-modeling platform initialized from raw observations, and completely independent from NWS-produced global model data.

Recent weather events, such as Hurricane Joaquin, highlight the superiority of Panasonic Weather Solutions' weather forecasting capabilities - from atmospheric data collection to high-performance numerical models that consistently run on an 11,000-core supercomputer named *Sora.* Panasonic is partnering with governments to enhance public safety, as well as leading corporations in multiple vertical markets to improve operational performance and become more environmentally friendly, with best-in-class weather forecasting. [7]

Global Interest in Panasonic Weather Models

Since the recent introduction of Panasonic's Global 4D Weather System, Panasonic Weather Solutions has received many requests for additional information about its weather modeling systems from meteorological agencies around the world.

This summer Panasonic Weather Solutions has been invited by the European Centre for Medium-Range Weather Forecasts (ECMWF) which is an independent intergovernmental organization supported by most of the nations of Europe; the Met Office of the United Kingdom (UKMET), the

[7] PR Newswire, Panasonic Weather Solutions Introduces Tropical 4D - Global Tropical Cyclone Forecasting, April 2016

official government meteorological agency for the United Kingdom; and the NOAA National Center for Environmental Prediction (NCEP) to make presentations on Panasonic weather modeling expertise.

Panasonic Corporate Information

Panasonic Weather Solutions is based in Morrisville, NC with additional offices in Lakewood, CO.
Panasonic Avionics Corporation is based in Bothel, WA with additional offices in Lake Forest, CA.

Panasonic Corporation of North America, based in Newark, NJ, is the principal North American subsidiary of Osaka, Japan-based Panasonic Corporation and the hub of its branding, marketing, sales, service, product development and R&D operations in the U.S. and Canada. Panasonic operations in North America include R&D centers, manufacturing bases, the award-winning Panasonic Customer Call Center in Chesapeake, VA, business-to-business and industrial solutions companies, and consumer products with sales and service networks throughout the U.S., Canada and Mexico.

Panasonic Corporation of North America and its subsidiaries and affiliates employ some 15,000 people in the region.

Bio for Dr. Neil Jacobs – Panasonic Avionics Corporation

Dr. Jacobs directs the research and development of both the tropospheric airborne meteorological data reporting system (TAMDAR), as well as the numerical models run by Panasonic. His areas of expertise include mesoscale dynamics, numerical weather prediction, and data assimilation. He is the chair of the American Meteorological Society's Forecast Improvement Group (FIG), and also serves on the World Meteorological Organization's (WMO) aircraft-based observing systems expert team. Prior to joining Panasonic (AirDat) in 2005, Dr. Jacobs worked on various analyses and modeling projects including NASA's Earth Systems Science Program, GOES satellite imagery, Department of Energy's Ocean Margins Program, and the National Weather Service's Atlantic Surface Cyclone Intensification Index. He has a BS in mathematics and a BS in physics from the University of South Carolina, a MS in air-sea interaction from North Carolina State University, and a PhD in numerical modeling from North Carolina State University.

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Chairman BRIDENSTINE. Thank you, Dr. Jacobs.
Dr. Busalacchi, you're recognized for three minutes.

TESTIMONY OF DR. ANTONIO BUSALACCHI, DIRECTOR, EARTH SYSTEM INTERDISCIPLINARY CENTER, UNIVERSITY OF MARYLAND

Dr. BUSALACCHI. Good morning Chairman Bridenstine and Ranking Member Bonamici, Members of the Subcommittee. Thank you for this opportunity to brief you again this morning.

Let me begin by noting today's weather enterprise is a triad that consists of the academic and research communities, the public sector, and the private sector. The government's traditional role within this triad is the protection of life, property and enhancement of national security. This public-sector role is grounded in sustainability and dependability of observational data and models that have free and open access. The private sector's traditional role is to create customized and tailored products to a broad customer base of private individuals and businesses in a multitude of sectors. The academic community works to improve our common understanding of your system, perform basic and applied research that leads to innovation, and trains the next generation of workforce both for the government and the private sector. The three work together in a public-private partnership that on the world stage is often the exception rather than the rule. This is a particular strength of our Nation's approach to the weather enterprise. These three pillars of success have yielded the world's most comprehensive and successful array of weather services in support of the public and private good.

While the roles of each of these legs of the weather enterprise must continue to evolve, weakening any single leg will compromise the entire enterprise and will negatively impact its diverse beneficiaries. We must also recognize that the private sector has been built upon and has benefited from the foundation of the free and open approach data and models. As a result of this tremendous investment from the public, there has been an enormous return to the public in terms of jobs and innovations.

I think we should act with caution so as not to do any harm and assure that the marketplace retains its competitiveness and no barriers to entry are neglected. In short, we need to find a workable method to strategically plan the entire enterprise.

The last major study from the National Academies, as you've heard, was the Fair Weather report of 2003. As a result of that report, NOAA worked to produce a policy to support dissemination of environmental information to the public that was beyond just weather data. In 2012, the Academies released a report on weather services for the Nation becoming second to none. That was an assessment of the National Weather Service modernization program. It had three main recommendations: prioritize core capabilities, evaluate function and structure, and leverage the entire enterprise, and that was the bulk of my written testimony.

I believe it is time to revisit these two reports but we are lacking a national strategy, and I think we run the risk of losing sight of the big picture. At one moment we may be occupied by the challenge of commercialization of satellite observations, the next mo-

ment by the potential private-sector models, and the next by procuring models from another country, all at the expense of what may be best for the country as a whole. I can easy see a scenario where company X takes publicly supported and freely available models and data and adds unique value to them. Company Y sells some data to the government but withholds some for its business purposes, and Company Z has its own proprietary models and data that are not available for the common good. Is this what is best for our Nation to protect lives, property, and support our military in the field?

Continued improvement in our forecasting ability requires that observations be reliable and accessible and forecasts for the public good be verified, validated and transparent.

Prior to taking on my new position with UCAR, I was co-chairing the next Decadal Survey for Earth Science and Applications from Space. As requested by the Congress, all of the space sciences have a long history of these decadal surveys that the agencies are beholden to as well as the insight they provide to you, OMB and OSTP. We have no such activity for the weather enterprise. Given the evolving nature of the weather enterprise, I would submit we need an active and ongoing strategic planning process as could be achieved by Congress requesting a decadal survey for the weather enterprise inclusive of midway assessments and subsequent follow-on surveys.

In closing, there is considerable upside potential for the Nation if we do it right. We have much to lose if we do it wrong. Thank you.

[The prepared statement of Dr. Busalacchi follows:]

Private Sector Weather Forecasting: Assessing Products and Technologies

Statement of

Antonio J. Busalacchi, Jr., Ph.D.

Director, Earth System Science Interdisciplinary Center (ESSIC),

University of Maryland

before the

Subcommittee on Environment

Committee on Science, Space and Technology

U.S. House of Representatives

June 8, 2016

Summary Statement of Antonio J. Busalacchi, Jr.

Today's weather enterprise is a triad that consists of the academic/research community, the public sector, and the private sector. The government's traditional role within this triad is the protection of life and property, and the enhancement of national security. This public sector role is grounded in the sustainability and dependability of observational data and models that have free and open access. The private sector's traditional role is to create customized and tailored weather products and services to a broad customer base of private individuals and businesses in a multitude of sectors. The academic community works to improve our common understanding of the Earth System, perform basic and applied research that leads to innovation, and trains the next generation work force for both the government and private sector. The three work together in a public-private partnership that, on the world stage, is often more the exception than the rule. This is a particular strength of our nation's approach to the weather enterprise. These three pillars of success have yielded the world's most comprehensive and successful array of weather services in support of the public AND private good. While the roles of each of these legs of the weather enterprise must continue to evolve, weakening any single leg will compromise the entire enterprise, and will negatively impact its diverse beneficiaries. We must also recognize that the private sector has been built upon and has benefitted from the foundation of the free and open approach to data and models. As a result of the tremendous public investment there has been an enormous return to the public in terms of jobs and innovation. From a policy perspective the companies we see here today are direct beneficiaries of our policy decisions 20 years ago. The real issue that confronts us is what do we want this enterprise to look like 20 years from now? I think we should act with caution so as not to do any harm, and ensure that the marketplace maintains its competitiveness and no barriers to entry are erected. In short, we need to find a workable method to strategically plan the entire enterprise.

The last major study from the National Academies that addressed the public-private interface in depth was the "Fair Weather" report of 2003. As a result of that report NOAA worked to produce a new policy to support the dissemination of environmental information to the public, which was more than just weather data. In 2012 the National Academies released a report on "Weather Services for the Nation: Becoming Second to None" that was an assessment of the NWS's Modernization program. The report had three main recommendations for the NWS: I. Prioritize Core Capabilities, II. Evaluate Function and Structure, and III. Leverage the Entire Enterprise. It is this last recommendation that I have dealt with most in my testimony. I believe it is time to revisit these two reports and re-assess, given the fluid situation in the weather enterprise, what the respective roles and responsibilities should be among the three pillars. We are lacking a national strategy for the entire weather enterprise and we run the risk of losing sight of the big picture. At one moment we may be occupied by the challenges of commercialization of satellite observations, the next moment by the potential of private sector models, and the next by procuring models from another country; all at the expense of what is best for the nation as a whole. I am concerned by the potential for fragmentation of our enterprise. I can easily see a scenario where Company X takes publicly supported and freely available models and data, and adds unique value to them, Company Y sells some data to the government but withholds some data for its business purposes, and Company Z has its own proprietary models and data that are not available for the common good. Is this what is best for our nation to protect lives, property, and support our military in the field? Continued improvement in our forecasting ability requires that observations be reliable and accessible, and forecasts for the public good be verified, validated, and transparent. Prior to taking on my new position with UCAR, I was co-chairing the next Decadal Survey for Earth Science and Applications from Space. As requested by Congress, all of the space sciences have a long history of these decadal surveys that the agencies are beholden to, in addition to the insight they provide to Congress, OMB, and OSTP. We have no such activity for the weather enterprise. Given the ever evolving nature of the weather enterprise I would submit we need an active and ongoing strategic planning process as could be achieved by Congress requesting a decadal survey for the weather enterprise inclusive of mid-way assessments and subsequent follow-on surveys. There is considerable upside potential for the nation if we do it right. We have much to lose if we do it wrong.

Good Morning Chairman Bridenstine and Ranking Member Bonamici, and members of the subcommittee. I am Dr. Tony Busalacchi and I am Director of the Earth System Science Interdisciplinary Center and Professor of Atmospheric and Oceanic Science at the University of Maryland. Prior to coming to the University of Maryland 16 years ago, I was a civil servant for 18 years at the NASA Goddard Space Flight Center (GSFC), the last 10 years of which I was a laboratory chief and member of the Senior Executive Service. Effective August 1, 2016, I will be the next President of the University Corporation for Atmospheric Research or UCAR. UCAR is a nonprofit consortium of 109 member universities granting degrees in atmospheric and related earth sciences. UCAR's primary activity is to manage, on behalf of the National Science Foundation, the National Center for Atmospheric Research (NCAR) and UCAR's Community Programs. NCAR is a Federally Funded Research and Development Center with over 600 scientists and engineers performing cutting-edge weather and atmospheric research, and staff that manages supercomputers, research aircraft, and Earth observing systems. The UCAR member universities and staff scientists conduct research for use by government and the private sector to further our understanding of atmospheric phenomena, and help to create more accurate weather forecasts across the nation.

As part of my responsibilities at NASA/Goddard I served as the source selection official for contracts to the private sector for observations and technologies. At the University of Maryland my group has entered into a number of Memoranda of Understanding and Non-Disclosure Agreements with the private sector involved in Earth observations and prediction. We also host a cooperative institute that is joint with NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) and the National Weather Service (NWS). From 2009 through 2014, I chaired the Board on Atmospheric Sciences and Climate (BASC) for the National Academies of Sciences, Engineering and Medicine. I believe that these experiences are directly relevant to this hearing and I will draw on them in my remarks below.

Following the suggestion in the committee's letter inviting me to testify, I will organize my testimony around the following questions that I believe are critical in examining the weather forecasting products and technologies of the private sector:

1. What constitutes the current weather enterprise and how did we get to our present state?

2. What key lessons can we glean from the development of the weather enterprise over time and what do they mean for the future of the enterprise?

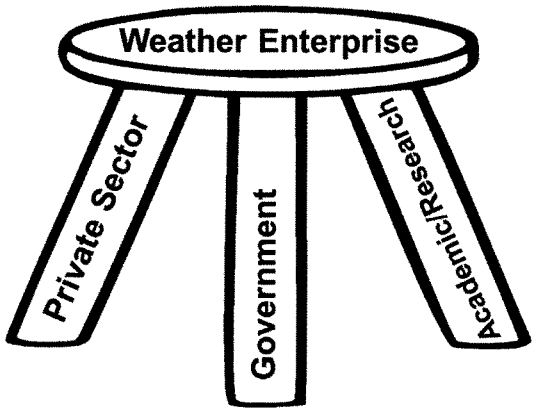
3. What is the forecast for the future of the weather enterprise?

4. What processes and policies are needed to identify roles and responsibilities? What, if any, are the next steps for Congress?

1. **What constitutes the current weather enterprise and how did we get to our present state?**

Today's weather enterprise is a triad that consists of the academic/research community, the public sector, and the private sector. The government's traditional role within this triad is the protection of life and property, and the enhancement of national security. This public sector role is grounded in the sustainability and dependability of observational data and models that have free and open access. The private sector's traditional role is to create customized and tailored weather products and services to a broad customer base of private individuals and businesses in a multitude of sectors. The academic community works to improve our common understanding of the Earth System, perform basic and applied research that leads to innovation, and trains the next generation work force for both the government and private sector. The three work together in a public-private partnership that, on the world stage, is often more the exception than the rule. This is a particular strength of our nation's approach to the weather enterprise. These three pillars of success have yielded the world's most comprehensive and successful array of weather services in support of the public AND private good. While the roles of each of these legs of the weather enterprise must continue to evolve,

the diminution of any single leg will compromise the entire enterprise, and will negatively impact its diverse beneficiaries.



The U.S. Weather Enterprise: consisting of the Government, Private Sector, and the Academic/Research Communities. Weakening any one leg of this triad weakens the whole. By working together we provide a solid foundation that well serves the nation.

This 3-way partnership has not always been the norm in our country's history. While Thomas Jefferson and Ben Franklin may vie for the title of America's "founding meteorologist", it was not until 1870 that the country decided to tackle weather in a more scientific manner. The Weather Bureau was established in 1870 in the Department of the Army Signal Corp and is in fact one of the few areas that has an actual organic act. The establishment of the Weather Bureau in the Department of the Army was for good reason; the military understood the implications and consequences of weather on military operations. History is filled with stories of campaigns shortened and empires ruined by bad weather. From Patton in the Bulge in 1944, to the sandstorms of 2003 in Iraq, and to the raid that killed Osama Bin Laden, weather has always been a factor in operations and it is as critical as ever to today's national security. Our combatant commanders in the field need and deserve the world's best actionable weather information.

There was, however, no private sector in 1870 making forecasts other than the Farmer's Almanac. The rise of the private sector in weather forecasting began after World War II as our veterans returned home. Today's capabilities of the private sector that rival certain aspects of the National Weather Service is a success story that has developed over the past several decades owing to three major factors;

a. Free and open data;

b. Modeling software that is free and open; and

c. The Information Technology revolution.

For years the model in the weather enterprise was government supported research to improve forecasting that was handed from the university community and federal labs to operational agents such as the National Weather Service at NOAA as well as within the Department of Defense. The government entities would then use those advances to improve forecast skill in their respective mission areas. This model changed rapidly in the 1990's with the modernization of the National Weather Service which occurred during a period of rapid growth in information technology capabilities. For the first time, foundational observational data, computer codes for numerical weather prediction models, and software technologies such as data assimilation (that merges the observations with the model information) were accessible to the private sector at no cost. Advances in information technology allowed private companies to access government data, download it, and add their own value to computer codes and observations to produce a suite of products that were tailored to meet specific customer needs. This heavy leverage of the government investment has enabled a private sector to flourish and develop a unique set of services and products.

The American Meteorological Society has compiled information that estimates the broad U.S. weather and climate industry at more than $5 billion, including some 250 commercial weather companies that generate roughly $2 billion. The recent acquisition of the Weather Company by IBM has been estimated to be a $2B purchase in and of itself. Why did IBM buy the Weather Company? IBM bought The Weather Company because there is now an opportunity to inject

weather forecasting and weather data into many more products and services enabled by rapidly developing information technology capabilities. As technology rapidly improves and it becomes easier and more cost-effective to perform more and more sophisticated weather forecasting operations, the triad – the private sector, government, and academia – will need to continually reassess what are the appropriate roles and responsibilities of each sector.

I believe the march towards commercialization will continue and we should all support commercialization. There is ample evidence to suggest that more weather operations can be performed easily, independently, and nimbly in this manner. Additionally, it is evident that there are opportunities for companies to incorporate rapidly developing technologies more quickly. As a case in point, one of my colleagues at the University of Maryland is collaborating with Panasonic Weather Services that funds one to two of his graduate students in this area of data assimilation. While it took nearly nine months to resolve intellectual property issues on both sides, this has proven to be a mutually beneficial collaboration. In addition to just the funding, on the university end there is ultimate flexibility in the experiments being run for the sponsor, ample supercomputing time, rapid turnaround time for experiments, and the students are exposed to the real-world needs of a specific sector/application that can only help to enhance their employment opportunities after graduation. It is also my understanding that a number of the personnel developing the data assimilation methodologies at Panasonic were formerly employed at NCAR. This is just one example of the vibrant and healthy working relationship between the research community and the private sector.

With respect to the government and the private sector, the National Weather Service relies on the private sector to disseminate and amplify public safety messages for high impact weather events. From the use of apps, to social media, to broadcast meteorologists personalizing NWS warning information, the private sector is critical to helping the NWS protect lives and property as part of its Weather-Ready Nation initiative. We need only turn on our TV at night to see that the NWS relies on the private sector to broaden access for the display, delivery, and archive of NEXRAD radar data. Therefore, the private sector is a critical partner in making real-time radar

data available to the broadcast media, emergency management community, and general public.

The NWS also operates several major programs that facilitate the purchase of data from the private sector, universities, and other non-federal operators of observing networks:

- The National Mesonet Program (NMP) was created by Congress following the 2009 release of the National Academies' report "Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks." A key recommendation of that report was for NWS and other agencies to leverage data from existing sources, where possible, in lieu of deploying new federal infrastructure to fill gaps in the nation's federal weather observing systems. Begun as a program to purchase data from a relatively small number of surface networks located mostly in the south-central United States, the program has now grown to encompass more than three dozen networks covering all 50 states, and is NWS's largest data purchase program.
- The Aircraft Based Observations (ABO) program is NWS's primary program for purchase of data from sensors mounted on commercial aircraft that serve major airport hubs domestically and globally.
- For many years, NOAA's Global Systems Division in Boulder provided observations of "total precipitable water" at 400+ locations across the United States, by processing the signals from ground-based GPS receiving stations at those locations. As it turns out, the GPS microwave signal is highly sensitive to atmospheric water vapor content. These data are very valuable to forecasting significant weather events where total atmospheric water content is a driving ingredient; such has heavy rainfall and flash floods. As part of the effort to transition this capability into NWS routine operations, NWS partnered with the private sector to process the signals and provide the precipitable water data, at a significantly reduced cost relative to what would be been possible with an in-house processing capability.
- Lightning Data, including the precise locations of cloud-to-ground strikes and the locations of in-cloud flashes, have been provided to NWS for many years by the private

sector, which operate many networks for that purpose and provide a cost-effective solution. These data are critical to fire weather forecasting operations and applications related to airport and aviation safety.

The government also engages the private sector for operational forecast model development and improvement. For example, AER, a private company, competed for and won Federal funding to develop a technical package to handle how radiant energy drives the atmospheric circulation in forecast models. The manner in which this is handled in weather prediction models can be very compute intensive. The first Rapid Radiative Transfer Model (RRTM) was implemented in August 2003. AER provided code to the NWS to test in the NWS' global prediction environment. RRTM provided an improvement to the model accuracy. The NWS and the Joint Center for Satellite Data Assimilation (JCSDA – including NOAA, NASA, and DoD) have since then maintained a long-standing relationship with AER for the treatment of radiation physics in these models. This has been a good partnership for both parties. Over the years this technical package has been updated and implemented in a range of different U.S. models. AER's code is recognized as being state of the science and is used by other weather prediction centers around the world.

With respect to collaboration between the government and the research community, the Weather Research and Forecasting (WRF) Model is a mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting needs. The model has served a wide range of meteorological applications across scales from tens of meters to thousands of kilometers. The effort to develop WRF began in the latter part of the 1990's and was a collaborative partnership principally among NCAR, NWS, the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA). WRF has also served as an important platform for the private sector to build upon.

We must also acknowledge that the growth of the private sector weather enterprise products and services has been built on the public investment, with a free and open data policy, and with forecasting technologies and techniques developed – and still developing – within the government and academic sectors. The government forecasts serve as a baseline standard by which private sector entities can and should compare their products and services. This has enabled considerable economic benefit to the U.S. due to this leveraging of the public data and models. We should be reminded that many of my fellow panelists have benefitted from this collaboration-based model. It is critical that this collaboration be maintained to support the next generation of private sector companies that will be able to develop products and services that will benefit our society and economy even further than this class of private companies has. I believe this is a great return on investment of public tax dollars and goes largely unnoticed. As the entire weather enterprise continues to mature, we must ensure that the American public remains well served. The best way of doing this is via a set of best practices and in continued partnership among the three pillars.

2. **What key lessons can we glean from the development of the weather enterprise over time and what do they mean for the future of the enterprise?**

   There are many lessons and insights that have been gained over time when it comes to understanding what improves weather models and their associated forecasting skill. I would like to focus on four areas that empower both public and private forecasts, and discuss why they are critical;

   a. Consistency of Data
   b. Quality Assurance of Models and Data
   c. Sustainability
   d. An Enterprise that must continually evolve to ensure greatest value to the nation.

Long-term continuous observations (aka, data) can be considered boring and mundane, but they are absolutely critical to making a forecast and accelerating improvement in forecasts locally, regionally and globally. The United States has benefitted tremendously from long-term satellite, airborne, and ground based data that has been derived from observations. It is essential that we maintain an optimal mix of this suite of observations as each has unique strengths related to the quality of high impact weather services. The U.S. has, in fact, been the global leader in this area and despite problems with some satellite programs; the overall record of federal support for long-term baseline operations has been rock solid. In fact the U.S. pioneered the use of weather satellites and assimilated those data into numerical weather prediction models in rapid fashion. The ensured provision and access to quality data over appropriate temporal and spatial resolution is essential and the U.S. has done this in partnership with international collaborators, and now more and more with the private sector. This trend will continue to play out, but a key question we need to answer is what data have the biggest impact on improving forecasting skill? We cannot purchase data just for the sake of purchasing it, but rather it must meet a validated forecasting requirement and ultimately improve forecast skill in a significant, cost effective manner. We must ensure that the data are readily available in the public domain and meet the standards for accuracy, quality, continuity, and reliability given that such data are needed to save lives and property, and support national security. Open assessment and verification of the data is critical. All of weather forecasting is singularly dependent on the long-tern availability of quality data.

It takes time to generate and properly use the observations in the forecast models and this is where the research enterprise and its academic leg have played a crucial role in helping to tease the signal from the noise. A great example in recent times that highlights a new paradigm is the aforementioned National Mesonet Program at the National Weather Service which is a "network of networks" ground based observing system. While mesonet observations today provide important data to support weather models, it is important to remember that there was a ramping up period to ensure that the observations were of

sufficient quality to go into the Numerical Weather Prediction models. This is a very important illustration of the three partners in the weather enterprise. Mesonets started as research tools in universities (starting with the Oklahoma mesonet), then morphed into privately run networks that now sell data to the National Weather Service and other private parties. Again, the blending of academic interest with a public need for data provided by a private company suggests how the weather enterprise can function to best serve the nation. All three parts of the triad are important. However, even to this day this day this is not a simple turnkey operation as improvements in network design, scope, and instrumentation continue within both the research community and private sector. Future evolution of the mesonet must be guided by good policy and solid technical requirements involving all parts of the triad.

It is also imperative to discuss the importance of quality assurance of models and data. One important reason for rapid progress in weather modeling is the community model concept. Given the scope and complexity of today's weather prediction models, the community model allows open and free access to new development which has contributed to continuous improvement of weather models. This must be maintained. In the case of a private company, when intellectual property is not shared, continued advancement for the entire enterprise as a whole can be hindered. We have seen examples where in the past a model was developed and licensed at one university, only to be surpassed in performance, over a short period of time, by open-sourced community developed models that draw on the best of the best and subsequently evaluated by various members of the community. In this field there is strength in numbers.

Across the national marketplace, companies claim superior products and services. Good business watchdog groups and government agencies hold those claims accountable and determine them false or accurate. In the open market it is *caveat emptor*. It is important that best practices and accountability measures are maintained to ensure that private weather models perform as well as their proprietors claim. Verification, validation, and

transparency are essential. This is particularly critical to establish if protection of life and property were to ever depend exclusively on private models. Given that improvements within the private sector are propriety and an important part of the business model, no one can verify that they got good results for the right reasons. Can their results be replicated? Are they testable? This is all part and parcel of the scientific method. Perhaps, there is the need for a third party, trusted agent, or honest broker to ensure accountability. Additionally, it is critical that government models persist to be held up as the gold standard for quality assurance. Because government modeling is so transparent with respect to the private sector (and academia even more so), works so closely with the research community for continuous improvement, and requires fidelity to protect life and property, government forecasts should be the benchmark for forecasting. This is a key public service role that the federal government will need to continue to play for many years.

Equally important is that the government currently and regularly distributes forecasts over multiple domains and time scales; across short, medium, and long range; from global to regional, and across atmospheric, ocean, coastal, hurricane, land surface and space weather domains. Given we are dealing with a coupled atmosphere-ocean-land system, to forecast for one domain, you ultimately need a system that functions well across space and time scales; i.e., a seamless approach to forecasting for which NCAR is helping to lead the way in this regard. Improvements will come from lessons learned in data assimilation, initialization, and other techniques honed in various modeling endeavors and communities. This is a huge challenge, and the unification of global and regional models is a major goal of the NWS' Next Generation Global Prediction System. Many of these domain and time specific forecasts are not currently attempted by the private sector. As private companies are profit driven, remote areas with low economic value may be neglected and underserved by the private sector if there is no government effort. The government must maintain, entrain, and obtain the capability and talent to perform well these modeling efforts.

Finally, many have addressed the issue of the sustainability of the observations. Over time the federal government has sustained the weather architecture on many fronts and this has resulted in basic services, products, and growth of the private sector. The government model is based on a public goods service model that has been acknowledged for quite some time. Due to indemnification, the federal government has the responsibility to make the forecast for the high-impact anomalous weather event. The government has been and will be there to make that forecast. One can reason this is exactly why government exists.

If the government relies on the private sector for critical data streams and those companies decide to exit the market we will see degradation in forecast quality. I believe we need to think about the sustainability of the data buy model as it pertains to weather. This is an issue I raised when I spoke to you this past November. Several years ago the DOD and the intelligence community stood up imagery companies with the thought that they could create a private market that was ancillary to their primary customer. Even though there has been 60 years of heritage for space-based imagery, when it came to leveraging off the national security investment, that market did not materialize and the two major companies in the field merged. That is a result I would not like to see anywhere in the weather enterprise.

Sustainability of efforts in the private sector is not just a figurative matter of life and death for those companies providing the data to the government. It is in fact a literal matter of life and death to those people who depend upon the forecasts that are generated through the use of that data—and it cannot be turned off. Much like the previous example this is a matter of national security. Similarly, sustainability in forecasting is critical as well. To achieve continuous advancement in weather modeling, existing and former models need to be readily accessible to judge improvement and reliability of new modeling efforts. NOAA's current Next Generation Global Prediction System process currently ensures that models of the future will be categorically and objectively better than models of the past. Nonetheless, the government needs to continually strive at accelerating and embracing innovation from

the academic/research and private sector parts of the triad while maintaining reliability. We simply cannot afford to accept the status quo. More can and needs to be done in this regard.

3. What is the forecast for the future of the weather enterprise?

Given that we have touched on how we got to the current state of the weather enterprise, I feel compelled to comment about the future and make a "forecast". I believe we will see greater international alignment on weather than we currently see, and we will see a role for both academia and the private sector in that future that is robust and productive. Furthermore, I believe we will see weather analytics and hyper local weather forecasts rise at a pace unseen in history with tremendous benefits to society everywhere and this will require the triad of interests to work together in an even more cogent manner.

Let me start by pointing out that during the Cold War, Soviet and American forecasters worked together and communicated regardless of what the situation was between Moscow and Washington. I make this point because despite how bad things were at a political level, the "forecasters culture" is one of cooperation and collaboration. This example epitomizes how weather is by its very nature international. Weather fronts that moved across the former Soviet Union are known today as "Siberian blasts" and "polar vortexes." People in Washington DC know these terms, but they emanated from relationships built decades ago and the fact is Soviet forecasters helped us and we helped them because it was the right thing to do.

While this is a bilateral example, we all realize that the globalization of weather and the ability to make quality forecasts has greatly benefitted lives across the planet. The establishment of the World Meteorological Organization (WMO) was to address the very nature of the global scope of weather. The WMO has over time focused on global cooperation and it is this global cooperation that has led us down the path of our current

hyper local forecasting capabilities that can now be done by both public and private sources across the planet.

The WMO has worked to establish data protocols and share information. That sharing led many in academia to get access to data to transform research results into better models and understanding of local and regional weather patterns. It also led many innovative companies to use that same data to create unique and specialized products to serve customers around the globe and expand weather products into new markets.

Moreover, I believe the future weather enterprise will be much more integrated today because individual countries cannot afford to build by themselves the complex tools such as satellites and models. They realize that by integrating their systems with other countries they will get a bigger return on their investments. Observations have led the way. In 2003 under the leadership of then Secretary of State Colin Powell, the United States led an effort called the Global Earth Observing System of Systems (GEOSS); a prime example of international coordination that leads to integration and alignment. The developed countries who are signatories to GEOSS bring large observing systems to the table. The developing nations that in the past treated their observations as national secrets bring those data or bring areas that have not had access to observations to the international community; associated products and services then result to the betterment of all. GEOSS did not start with technologies, but focused on nine societal benefit areas and then worked from those to develop areas that needed to be addressed by technologies. GEOSS is represented at the WMO as an ad hoc organization and is referred to as the Group on Earth Observations (GEO). Any country can access data if it is a signatory. What the WMO and GEO have done is create alignment in weather never seen before. As a result, the private sector in the United States has access to these data to reach markets everywhere. Perhaps in the future we will see global alignment in regards to weather modeling and data assimilation. We are not there yet, but it is clear that by working together, the meteorological services around the world, and their associated researchers in universities and the private sector, will all benefit from this collaborative model of alignment.

Finally, this alignment in our own country has already resulted in private sector weather analytics and hyper local forecasts that address a variety of events in a fashion unheard of even 10 years ago. Several of the people on this panel have hour-by-hour forecasts that provide users with real time data matched with GPS to a site-specific location. Some on this panel use open source models, then add their own proprietary data and/or technologies to deliver aviation forecasts that make air routing more efficient. Others target specific components of the energy sector to meet emerging wind and solar forecast requirements. The opportunities for new hyper local industry specific forecasts in the United States and abroad are nearly limitless. We now see this as normal in the digital age, but it is a relatively new phenomenon. This market is in its infancy.

The emergence of hyper local forecast products requires more computational power and models that scale from a global to regional to local level. It requires three-way cooperation among all members of the weather triad to ensure that the public knows the values and limitations of these capabilities. It also requires government and private sector research investment to keep the United States on the cutting edge in delivering these products and services.

4. What processes and policies are needed to identify roles and responsibilities? What, if any, are the next steps for Congress?

Clearly, the weather enterprise is dynamic and it relies on all three participants. What can Congress do to leverage the best forecast at the least cost? What is the role of the public sector given we have emerging capabilities in the private sector we could not have imagined 20 years ago? What is the best path forward? Are government and academia making best use of existing vehicles for collaboration with industry such as SBIR and STTRs? These are salient questions. At the same time we must recognize that the private sector has been built upon and has benefitted from the foundation of the free and open approach to data and models, and as a result of the tremendous public investment there has been an enormous return to the public in terms of jobs and innovation. From a policy perspective the

companies we see here today are direct beneficiaries of our policy decisions 20 years ago. The real issue that confronts us is what do we want this enterprise to look like 20 years from now? I think we should act with caution so as not to do any harm, and ensure that the marketplace maintains competitiveness and no barriers to entry are erected. In short, we need to find a workable method to strategically plan the entire enterprise.

From my perspective we need to support, encourage and promote collaboration across the academic, government, and private sectors. My future organization UCAR/NCAR has a strong and proven track record in this regard. UCAR/NCAR has served admirably over the years as an effective and efficient conduit for interaction with both the government and the private sector. Programs like the Research Transition Acceleration Program (RTAP) at NOAA are trying to bridge the notorious valley of death between fundamental research and application. RTAP would prioritize projects based on opportunities to advance NOAA's mission. NOAA funded research projects identified for transition will be evaluated and prioritized for funding based on a common set of criteria, including mission criticality, societal benefit, early stakeholder engagement, and plans for reliable delivery of products and services. When appropriate, RTAP funds could be used to transition research performed by other government agencies and non-governmental entities. NOAA is not averse to the idea that the research or operations program managers could be non-NOAA managers – or not be funded by NOAA. The only requirements for receiving RTAP funding, be it the private sector or academic sectors, would be that a technology to be transitioned must meet the common criteria, advance NOAA's mission, and fulfill a NOAA-mission application or operational need.

Bridging the valley of death is not just a bridge from academia to public sector organizations, but it has to be a series of bridges with flow in both directions: academia to/from the private sector, academia to/from the government, private sector to/from the government. Obviously, these bridges will not be easy to construct and maintain when dealing with delicate matters such as intellectual property, but the barriers are not insurmountable. Programs such as RTAP and others can ensure that the government's

continuous role in weather forecasting can be a source of opportunity for continued improvement of modeling in the academic and private sectors, and for all products and services that the country relies on.

Furthermore, the government acquisition cycle can no longer keep pace with the academic and private sector innovation cycles. Our ability to innovate in areas like weather analytics are tailor made for new and exciting commercial products. Weather is big business and growing, but how do we define the terms of engagement for the various participants so that competition can flourish and obstacles can be addressed before they emerge?

Are we are at the point where Congress directs the National Weather Service to focus only on the high impact anomalous event and remove itself from day-to-day forecasting? Some might say that the day-by-day forecasting can be handled by Artificial Intelligence, i.e., that off the shelf machine learning algorithms could take a model forecast and automatically generate maximum and minimum temperatures without much need for the private sector. Is it the proper role for the government to maintain the back bone in collecting the essential observations and making high resolution global forecasts that are freely available? Clearly to date, this has enabled the private sector to derive products to serve their customers. At a minimum, we need to make sure that essential data are collected to support forecasting and be easily accessible; regardless if it is done by the government or private sector. It is also essential that high quality, high accuracy forecasts be available for the protection of life and property, and support of national security. I think it would be a mistake if we were to ever find ourselves dependent on any one single company. Let us also not lose sight of the fact that most of my testimony pertains to tomorrow's weather. This is undoubtedly important, but society is increasingly recognizing the need for improved weather predictions on subseasonal to seasonal time scales. Earlier this year the National Academies issued a report on "Next Generation Earth System Prediction: Strategies for Subseasonal to Seasonal Forecasts" that I helped initiate when I chaired BASC. With this information, planning and design decisions can be made that reduce our vulnerability to tomorrow's weather before it arrives. A case can be made that this is the single best weather related

investment in the future that Congress could make. I make these statements to make a point. There are serious policy considerations that deserve review and attention from Congress and the weather community.

The last major study from the National Academies that addressed the public private interface in depth was the 2003 Fair Weather report on "Effective Partnerships in Weather and Climate Services." That was 13 years ago and much has happened since then. As a result of that report, NOAA worked to produce a new policy to support the dissemination of environmental information to the public, which was more than just weather data. In 2012 the National Academies released a report on "Weather Services for the Nation: Becoming Second to None" that was an assessment of the NWS's Modernization program. This report addressed three main challenges:

- Keeping Pace with accelerating scientific and technological advancement.
- Meeting Expanding and Evolving User Needs in an increasingly information-centric society.
- Partnering with an Increasingly Capable Enterprise that has grown considerably since the time of the Modernization Program.

The report had three main recommendations for the NWS: I. Prioritize Core Capabilities, II. Evaluate Function and Structure, and III. Leverage the Entire Enterprise.

It is this last recommendation that I have dealt with most in this testimony. I believe it is time to revisit these two reports and re-assess, given the fluid situation in the weather enterprise, what the roles and responsibilities are now and should be in the future given our changing environment in the field. We are lacking a national strategy for the entire weather enterprise. Until and unless all three parts of the triad give their best effort toward a strategic planning process, we will run the risk of losing sight of the big picture. At one moment we may be occupied by the challenges of commercialization of satellite observations, the next moment by the potential of private sector models, and the next by procuring models from another country; all at the expense of what is best for the nation as

a whole. I am concerned by the potential for fragmentation of our enterprise. I can easily see a scenario where Company X takes publicly supported and freely available models and data, and adds unique value to them, Company Y sells some data to the government, but withholds some data for its business purposes, and Company Z has its own proprietary models and data that are not available for the common good. Is this what is best for our nation to protect lives, property, and support our military in the field? Prior to taking on my new position with UCAR, I was co-chairing the next Decadal Survey for Earth Science and Applications from Space. As requested by Congress, all of the space sciences have a long history of these decadal surveys that the agencies are beholden to, in addition to the insight they provide to Congress, OMB, and OSTP. We have no such activity for the weather enterprise. Given the ever evolving nature of the weather enterprise I would submit we need an active and ongoing strategic planning process as could be achieved by Congress requesting a decadal survey for the weather enterprise inclusive of mid-way assessments and subsequent follow-on surveys. There is considerable upside potential for the nation if we do it right. We have much to lose if we do it wrong.

ANTONIO J. BUSALACCHI, JR., is Director of the Earth System Science Interdisciplinary Center (ESSIC) and Professor in the Department of Atmospheric and Oceanic Science and at the University of Maryland. He also chairs the University of Maryland Council on the Environment. Effective August 1, 2016, he will serve as the next President of the University Corporation for Atmospheric Research (UCAR). Antonio J. Busalacchi received his Ph.D. degree in oceanography from Florida State University in 1982. He began his professional career that year at the NASA/Goddard Space Flight Center. He has studied tropical ocean circulation, its role in the coupled climate system and phenomenon such as El Nino. His interests include the development and application of numerical models combined with in situ and space-based ocean observations to study the tropical ocean response to surface fluxes of momentum and heat. His research on climate variability and predictability has supported a range of international and national research programs dealing with global change and climate, particularly as affected by the oceans. In 1991, he was appointed as Chief of the NASA/Goddard Laboratory for Hydrospheric Processes, and member of the Senior Executive Service (SES). In year 2000, he was selected as the founding director of ESSIC at the University of Maryland. Dr. Busalacchi has been involved in the activities of the World Climate Research Program (WCRP) for many years. From 2008-2014 he chaired the Joint Scientific Committee that oversaw the WCRP. He previously was Co-Chair of the scientific steering group for its subprogram on Climate Variability and Predictability.

He has served extensively on National Academy of Science/National Research Council (NAS/NRC) activities, including as Chair of the Board on Atmospheric Sciences and Climate, Chair of the Climate Research Committee, Chair of the Committee on Earth Science and Application: Ensuring the Climate Measurements from NPOESS and GOES-R, as Co-chair of the Committee on National Security Implications of Climate Change on U.S. Naval Forces, and as a member of the Committee on Earth Studies, Institute of Medicine Committee on the Effect of Climate Change on Indoor Air Quality and Public Health, Committee on Assessing the Impacts of Climate Change on Social and Political Stresses, and Committee on the Assessment of NASA's Earth Science Program. Dr. Busalacchi currently serves as Co-Chair of the NRC's Decadal Survey on Earth Science and Applications from Space, and he also serves on the Intelligence Science and Technology Experts Group (ISTEG).

In 2016, he was elected to the National Academy of Engineering (NAE). In 2014 he was elected as Chair of the American Association for the Advancement of Science (AAAS) "Section W" on Atmospheric and Hydrospheric Sciences as well as being elected as a Trustee to the University Corporation for Atmospheric Research (UCAR) Board of Trustees. Professor Busalacchi has received numerous other awards and honors. Among these, in 1991, he was the recipient of the prestigious Arthur S. Flemming

Award, as one of five outstanding young scientists in the entire Federal Government. In 1995 he was selected as Alumnus of the Year at Florida State University, in 1997 he was the H. Burr Steinbach Visiting Scholar at Woods Hole Oceanographic Institution, in 1999 he was awarded the NASA/Goddard Excellence in Outreach Award and the Presidential Rank Meritorious Executive Award. He is a Fellow of the American Meteorological Society (AMS), the American Geophysical Union (AGU), the American Association for the Advancement of Science (AAAS), and in 2006 was selected by the AMS to be the Walter Orr Roberts Interdisciplinary Science Lecturer. As part of his broader professional interests Busalacchi builds on his family background and also provides a broad range of consulting services including wine education, wine list and wine program consulting, and viticultural weather and climate forecasting services, nationally and abroad via www.VinoVeritasLLC.com.

Chairman BRIDENSTINE. Thank you, Dr. Busalacchi.
Dr. MacDonald, you're recognized for three minutes.

TESTIMONY OF DR. SANDY MACDONALD, DIRECTOR, NUMERICAL WEATHER PREDICTION, SPIRE GLOBAL

Mr. MACDONALD. Chairman Bridenstine, Ranking Member Bonamici, and Members of the Committee, I retired from NOAA in January after 40 years, fabulous organization. I signed on to Spire Global Incorporated, which is a company that's going to use small satellites to I think bring revolutionary changes to our ability to observe the weather.

I started my career as a young weather officer giving weather briefings, and the truth is, we had almost no information. The pilots, their lives depended on what we could tell them, and we knew very little. I'm sure our Chairman could vouch for that occasionally.

But it's a different world now. The government, originally a sole player in those days, I think has now been enhanced by our growing commercial sector, which I think if we have the right policies, we can have a fabulous partnership between the academic, the public and the private weather capabilities to serve this country.

I'll give a couple examples. I was, back in about the year 2000, part of a group who said let's have a community model, the weather research and forecast model, and I think NCAR and NOAA and others, NASA, worked on this but the big thing that I think that happened was, NCAR basically said we're going to make this a real community model to support it, to not have intellectual-property issues and other issues get in the way, we'll have workshops and so on. It's been a huge success. So it's a great example of private-public partnership. I think the fact that the Panasonic model that Neil Jacobs talked about used the Weather Service GFS model is another example of that.

I'd like to talk about the satellite observing systems. I think that the private sector can really bring some dynamism and complementary to the federal sector in satellites, and a good example of that is Spire, the company that I work for. We all remember when we went from mainframes to PCs. I think that's what Spire is trying to do with satellites. They're trying to take a big, expensive technology, put it down in a little tiny box, and still get incredible quality out of it. So they propose to generate radio occultations from cubesats. I think they're going to have probably 30,000, 40,000 next year, and their goal is 100,000 COSMIC 1-quality radio occultations. This is like having a radiosonde balloon that has a sounding for every degree of lat and longitude over the entire globe.

I think it's important that we protect our federal sector. It's really what we depend on for safety, for working on Earth system issues. Examples of those are COSMIC 2. We know that GOES–R and JPSS are going to have a fabulous set of sensors. It's really important that we have the private sector be complementary to that.

Finally, I'd like to say I think the sort of strength of the U.S. is its ability to mix the advantages of public and private, and I think that's our job here to do that in the weather business.

Thank you.

[The prepared statement of Mr. MacDonald follows:]

WRITTEN STATEMENT OF
ALEXANDER E. MACDONALD, PH.D.

DIRECTOR, NUMERICAL WEATHER PREDICTION
SPIRE GLOBAL, INC.

"WEATHER PRODUCTS AND TECHNOLOGIES OF THE PRIVATE SECTOR"

BEFORE THE
SUBCOMMITTEE ON ENVIRONMENT
HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

Chairman Bridenstine, Ranking Member Bonamici, and Members of the Committee, it is a distinct honor to testify again before the House Committee on Space, Science and Technology. I retired from the National Oceanic and Atmospheric Administration (NOAA) in January after over 40 years as an Air Force officer and federal executive. I am now employed by Spire Global, Inc., a company that plans to use small, sophisticated satellites to bring revolutionary improvements to weather observing. It is fascinating to see the differences and similarities between my federal service and work in a private company.

When I was a young officer giving weather briefings to Air Force pilots, the information we had was poor. The tremendous progress we have made since then is testimony to the visionaries who believed in science, observations, and computers to deliver better forecasts, but mainly to the nation for its support of the weather community. Recent successes, forecasting of blizzards and hurricanes days in advance, show that we have come a long way, while some recent busts or near misses show we can do better. I believe that the best route to continued improvement of weather prediction must be based on the right combination of public and private contribution to weather observing and modeling.

There was a time when almost all weather infrastructure was developed, purchased and operated by the federal government. However, during recent decades, we have seen a vibrant and growing private sector weather role, including providing weather forecasts to users, creating observing systems, and running state-of-the-art weather models. The reason for the growth of commercial weather businesses is the increasing skill of weather prediction, which generates products that are valuable in the marketplace and can generate revenue. This can lead to enhancements of weather capabilities if policies are in place that encourage the innovation and investments that the commercial sector can bring, while maintaining the crucial services of government, such as assuring public safety. Conversely, it is conceivable that existing policies would carry on with enough inertia from the past that these new commercial opportunities would be lost.

It is good to provide examples. Twenty years ago, operational numerical weather prediction was the exclusive purview of government. I am proud to say that I was among the people who encouraged the development of a regional community model, the Weather Research and Forecasting model, which was developed between the National Center for Atmospheric Research

and NOAA. Now that model is used by the National Weather Service, and worldwide in many commercial applications. More recently, the Panasonic Corporation announced that its global weather model was the most skillful in the world – its "anomaly correlation" was better than the European Center for Medium Range Weather Prediction (ECMWF), the US model, and all the others. This is an exciting advance, but it did not occur out of thin air. They started with NOAA's Global Forecast System model, and made improvements, added data from aircraft, and invested in a large development staff over 10 years. The US has a community modeling approach, which helped enable the Panasonic team to create their model. US policy should assure that the primary foundational modeling capabilities, including both research and operations, be supported in NOAA and the federal sector, while allowing commercial companies to use community capabilities to create the best observing and modeling they can.

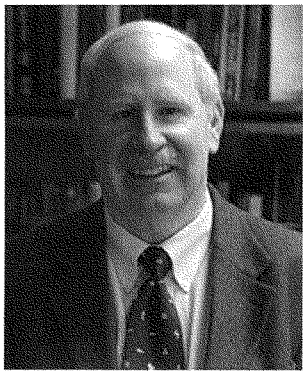
The situation is similar for satellite observing systems. While many believed the rockets and satellites would always be the sole purview of government, it is obvious now that the private sector brings a dynamism and complementary advantages to the space business. A great example of this is the company I work for, Spire. This is a small start-up with an immense ambition - build and deploy dozens of small cubesats to do jobs that were previously only done by big, expensive satellites. To me, it's a repeat of the evolution from main-frame computers to PCs in the 1980s. We have experience with the contribution of "Radio Occultations" to weather prediction because of our experience with the COSMIC program. Spire proposes to have a large constellation of satellites that we plan can deliver tens of thousands of Radio Occultations by late next year, with a goal of 100,000 "COSMIC 1 quality" ROs per day. This is the equivalent of a radiosonde balloon providing accurate temperature and moisture soundings for every degree of latitude and longitude every 12 hours over the whole globe! As someone who has been involved with weather modeling for 40 years, I believe this could be the biggest advance yet in weather observations.

It is important to add, however, that the global weather observing system that we have put in place among the international community, led by the US, must be preserved and enhanced. The COSMIC 2 program has a significantly enhanced Radio Occultation (RO) system that would show the direction RO should go in the future, and provide a base of data available under WMO 40. The NOAA GOES R and JPSS satellites have a fabulous suite of sensors that are necessary for weather prediction and our global Earth system science needs.

My closing thought is that we are on the threshold of big improvements in weather predictions. I hope to see the skill we now have on hurricanes and major snowstorms at three days, be extended to five days before I really retire! The new satellite observing systems funded by governments, complemented by the capabilities coming available in the commercial sector (including RO, geostationary hyperspectral and other systems) will make the full system more robust. If we had a major disruption in our JPSS schedule, federal and commercial Radio Occultation satellites could save the day.

It is gratifying to be in a country that can mix the advantages of private and public capabilities as effectively as the US does. We have an opportunity to do just that in the weather arena.

Alexander E. "Sandy" MacDonald



Dr. Alexander E. (Sandy) MacDonald retired from over 40 years of federal service in the National Oceanic and Atmospheric Administration, on January 3, 2016. He was a Senior Executive since 1990 and President of the American Meteorological Society in 2015. He retired after 10 years as Director of NOAA's largest research laboratory, the Earth System Research Lab in Boulder, Colorado. He was Chief Science Advisor for NOAA's research line, and it Deputy Assistant Administrator from 2006 to 2012. He was Director of NOAAs Forecast Systems Laboratory from 1988 to 2005. He is the inventor of NOAA's Science On a Sphere, an educational exhibit now in over 130 museums worldwide. He worked with Vice President Al Gore to start the GLOBE Program in 1994. He is the recipient of four Presidential Rank Awards.

Dr. MacDonald recently published (January 25, 2016) an article in *Nature Climate Change*, titled **"Future cost-competitive electricity systems and their impact on US CO_2 emissions"** that was ranked in the 99th percentile of impact by *Altimetric*. The article presents results that show the US could reduce its carbon dioxide emissions by up to 80% by 2030, by implementing a High Voltage Direct Current transmission network. The article presents a solution to greenhouse gas emissions that could be implemented now with existing technology, and would be also be feasible in other major economies such as Europe, China and India.

On April 4, 2016 he joined Spire Global, where he is leading a group that is developing global weather models and advanced energy solutions.

Contact
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Curriculum Vitae

EDUCATION

Ph.D. in Meteorology (Minor in Computer Science), University of Utah, 1975
M.S. in Meteorology, University of Utah, 1973
B.S. in Mathematics/Physics, Montana State University, 1967
USAF Weather Course Certificate in Meteorology, St. Louis University, 1968

PROFESSIONAL EXPERIENCE

2006 - 2016	Deputy Assistant Administrator, Laboratories and Cooperative Institutes, OAR Director, Earth System Research Laboratory, NOAA
1988 - 2006	Director, Forecast Systems Laboratory, NOAA
1983 - 1988	Director of the Program for Regional Observing and Forecasting Services (PROFS), Environmental Research Laboratory (ERL), NOAA
1980 - 1982	Chief of PROFS, Exploratory Development Group, ERL, NOAA
1975 - 1980	Techniques Improvement Meteorologist in the Scientific Services Division, Western Region National Weather Service, NOAA in Salt Lake City
1973 - 1975	University of Utah - Research Fellowship
1971 - 1973	University of Utah - Instructor, Synoptic Meteorology Laboratory
1967 - 1971	Officer, U.S. Air Force

MEMBERSHIP IN PROFESSIONAL SOCIETIES

President, American Meteorological Society, 2015
American Meteorological Society
National Weather Association

RESEARCH INTERESTS

Dr. MacDonald has published in atmospheric modeling, statistics, dynamics, and meteorological systems. His interests are applications of science and technology to improve operational forecasting.

ACTIVITIES

2005	Patent #6,937,210, "Projecting Images on a Sphere", Alexander E. MacDonald
2002	Patent #6,421,010, "Atmospheric Sondes and Method for Tracking", Russell B. Chadwick and Alexander E. MacDonald
1994	Executive Committee Member, AMS; AMS Fellow
1993	Developed GLOBE Program (a Vice-Presidential Initiative)

1992	Councilor, AMS three-year appointment
1983 - Present	Lecturer at numerous AMS chapters throughout the United States.
1987 - Present	Member, AMS Committee on Aviation, Range, and Aerospace Meteorology
1984 - Present	Member, Panel on Mesoscale Research, NRC
1988 - Present	Fellow with the Cooperative Institute for Research in the Atmosphere - Colorado State University

AWARDS

2009	Presidential Rank Award - Distinguished
2007	Presidential Rank Award - Meritorious
2001	Presidential Rank Award - Meritorious
1997	Presidential Rank Award - Distinguished
1993	Gold Medal - Leadership in Technology Transfer
1980	Bronze Medal - Accomplishments in NWS AFOS Program

Chairman BRIDENSTINE. I'd like to thank all the witnesses for their testimonies.

Members are reminded that Committee rules limit questioning to five minutes, and I'll start by recognizing myself for five minutes.

Dr. Jacobs, I wanted to start with you. Panasonic has its own numerical weather models, and Panasonic uses its own data in some cases, and in many cases uses data from NOAA and other sources as well. Can you share with us your weather forecasting models? How does that compare to the GFS—the Global Forecasting System—or the European model? How is your model comparing to the others?

Dr. JACOBS. So that's correct. We use our own data. We bundle that with all the publicly available data. We assimilate that into a suite of different models, our flagship model being a global model. It differs slightly from NSEP's in both the data assimilation scheme as well as a lot of the modifications and the physics. Its performance really depends on how you verify it. If you verify it through sort of the standard anomaly correlations, it's slightly ahead of NSEP. The European center had a major upgrade in March. It's slightly lagging the European center. If you verify it through other means, particularly case studies, there's been some major weather events over the last two years where it's outperformed both.

If you actually consider the fact that we have complete control over the system that's fully customizable from a business perspective, it's highly advantageous because we can write out files in increments, levels and variables that you wouldn't normally get from the government center because our motivation is actually helping other businesses. We believe that the Weather Service's mission is to protect life and property.

Chairman BRIDENSTINE. Has anybody from NOAA or the Department of Defense reached out to you to get information on how you're able to accomplish this?

Dr. JACOBS. Yes. I actually have some meetings at the Pentagon lined up shortly. I'll be giving a seminar next month on some of our data assimilation methods. Our software engineers are in constant contact with the NSEP, and to the extent that it doesn't negatively impact our business model, we do share information with them.

Chairman BRIDENSTINE. And the intent with the model is to what? You want to license the outcomes, the outputs of your model? Is that your intent?

Dr. JACOBS. Well, the primary intent would be to customize and develop products and applications to sell to other industries. They would be products that you can't normally derive from the publicly generated weather model data. As far as the government agencies are concerned, the possibility of licensing some of the software does exist.

Chairman BRIDENSTINE. And my understanding is, your model is a global model to establish the global initial conditions for weather forecasting. Can you share with us, does your model have the ability to do mesoscale forecasting or even microscale forecasting for my constituents that are obviously hit with severe weather from time to time?

Dr. JACOBS. Right. So one of the reasons why we decided to run our own global model is, every regional model needs what they call boundary conditions provided by a global model. So we run the global model to provide lateral boundary conditions to high-resolution nested regional models. We currently run several different nested regions running from 4 to 2–1/2 kilometers, and within those nested regions we can have high-resolution domains down to sub-one kilometer.

Chairman BRIDENSTINE. Got it.

And Mr. Block, how has NOAA reacted to your innovation with weather modeling and forecasting?

Mr. BLOCK. They have expressed considerable interest in the—especially in the ag weather network data that we provide, and we look forward to working more closely with them to figure out how we can use that information or even extend or expand that information to add things like soil temperature or soil moisture to the observations we make.

Chairman BRIDENSTINE. Awesome.

Dr. MacDonald, how many GPS radio occultation sensors has Spire launched to date?

Mr. MACDONALD. So far, I think we're kind of at the beginning. We actually have four satellites and then two test satellites, and we're just learning how to get the quality out of them that we need.

Chairman BRIDENSTINE. And is your intent to establish your own numerical weather models as well or to piggyback on the numerical weather models of others?

Mr. MACDONALD. Our intent is not to establish our own weather models except to the extent that we want to be able to test the value of these so that we can talk to our customers and show that it's valuable.

Chairman BRIDENSTINE. So your objective would then be to provide a service to others that are providing the model? It could be Panasonic, it could be NOAA, it could be others?

Mr. MACDONALD. That's correct.

Chairman BRIDENSTINE. Okay. I've been encouraged that NOAA is moving forward with the commercial weather data pilot as outlined in the bipartisan House-passed weather bill, H.R. 1561. I'm very pleased with that.

Dr. MacDonald, can you give me your take on NOAA's approach to working with the private sector to incorporate data such as Spire data into their weather models?

Mr. MACDONALD. I think that we have to see about the future. I think the ideas in the Fair Weather Act and the experience already with private data being available that Neil Jacobs just talked about shows that the path is there, so we're hoping that we can have that partnership with the data also.

Chairman BRIDENSTINE. Excellent.

And I'd like to—my time is out. I'll recognize the Ranking Member from Oregon, Ms. Bonamici, for five minutes.

Ms. BONAMICI. Thank you very much, Mr. Chairman. Thank you to all the witnesses for your testimony.

Dr. Busalacchi, a well-funded and forward-thinking Weather Service is critical for the continued protection of the lives and public of the American public, and we certainly heard that recognition

not just from you but from others today, and we want continued growth.

You mention in your testimony the need for a national strategy, so I'm going to ask you about a couple of things, and then I want you to talk about what you envision as part of the national strategy. One, should we be investing in greater supercomputing capacity for the Weather Service, and if so, what would be the needs for optimal model runs? And then also, Dr. Block mentioned in his prepared statement that NOAA should leverage the examples of other agencies and have regular committee or working groups that include the private-sector members. So do you have any perspectives on that idea? Are there other models that may be considered? And what would you envision as a national strategy?

Dr. BUSALACCHI. Thank you very much. So with respect to supercomputing, the answer is yes, but—so if you look at one of the reasons why for this medium-range time scale for weather, predicting weather on time scales from three to five to seven days, one of the reasons why we're about ten years behind the Europeans is in part because of supercomputing, but as a result of your encouragement, NOAA is now at the forefront worldwide in supercomputing capability at this instant. What we lack is the budgetary, the planning process to keep us there, all right? In years past we were behind the Europeans. We're now at the forefront but for a snapshot. One problem. So we need to solve that.

The second problem is this whole topic of transition from research to operations so that the Nation can take the best of the best wherever it comes from, not just the private sector but from academia as well. Europeans are much better at doing that transition from research to operations. NOAA has a plan called RTAP, Research Transition Acceleration Program, that is going to try and move that. I think that's in the right direction. But one of the challenges going forward with respect to a strategy—so Mr. Block's recommendations are very consistent with what were in the Fair Weather report of 2003, 13 years ago. One of the challenges there is follow-up. I don't think we need another report onto itself but we need a process.

So over the years I've done something like 20 different National Academy reports. Oftentimes those reports end up on a shelf collecting dust because there's no follow-up, and that's why I recommended a decadal survey because it's mandated by you. The agencies need to show cause if they differ from the recommendations in the decadal survey. Five years into the process—I mean after the report is written, there's a midterm assessment to see whether or not the agencies are doing what was encouraged, and then five years after that, there's another decadal survey. So it's a process, it's not a one-off activity. And it's not—we're not talking here about a bunch of academics. It is this three-legged stool. One-third of my colleagues here from the private sector, one-third from academia, and you couldn't have the feds at the table but you could have one-third composed of former senior government officials now in industry like Sandy MacDonald. Myself, I spent 18 years in NASA as an SESR, then went into academia. So you have—you're taking advantage of the best of the best.

Ms. BONAMICI. Dr. Busalacchi, I don't mean to interrupt but I want to get another question in before my time expires.

The employees of the National Weather Service work tirelessly to serve our communities and assist, for example, with natural disasters. My State of Oregon and the Northwest have faced severe wildfires. Weather Service employees have provided specialized forecasts tailored to those wildfires to help firefighters safely and effectively extinguish them.

So the National Weather Service is a public good, so could you explain why it's important that the Weather Service provide the baseline forecasts? What other benefits are there of having government-provided publicly accessible forecasts?

Dr. BUSALACCHI. So again, the vast majority of what my colleagues have spoken to about here are founded upon the publicly available forecasts and the data, and again, in terms of the role of the government, in terms of protecting public life, infrastructure and, again, homeland and national security, we need to have the best of the best, and that goes back to this three-legged stool: having the private sector engaged, having academia and the research engaged, and having a strong partner in the government as well. That's, in my opinion, the only way that we could have the best of the best and compete with the Europeans.

Ms. BONAMICI. Terrific. Thank you.

My time's about to expire. I yield back. Thank you, Mr. Chairman.

Chairman BRIDENSTINE. I thank the Ranking Member.

As I pass the baton here for one second, I'd like to get Dr. MacDonald to respond to Dr. Busalacchi. You mentioned that the movement from research to operations is going well. Dr. MacDonald, do you agree with that? When you think about the high-resolution rapid refresh model, didn't that sit on the shelf for years?

Mr. MACDONALD. I think the high-resolution rapid refresh should have gone faster but I think it's a pretty fabulous model and I'm exciting about that accomplishment.

In terms of how well we do research to operations, I think a major point is that we can always do better. I think we learned a lot where we said okay, we're going to have these big community models and everybody can work on them. The point that I'm making is, we did that for the regional models. I think we want to do that now for the global models, and I think it's crucial.

Chairman BRIDENSTINE. Dr. Busalacchi, you're recognized.

Dr. BUSALACCHI. Thank you very much. Let me be very clear. I think that's one of the fundamental differences between us and the Europeans. I think the Europeans do a much better job of the transition from research to operations, so again, what I was trying to say is, we need to do better at sustaining computing and we need to do a much better job of transition of research to operations from the research community as well as the private sector.

Chairman BRIDENSTINE. Got it. Okay.

I'd like to recognize Mr. Weber from the State of Texas for five minutes.

Mr. WEBER. Thank you, Mr. Chairman.

These will be for Dr. Jacobs. I'll start with you. Dr. Jacobs, in your experience, in your opinion, does the federal government and

NOAA facilitate, hinder or resist commercial weather opportunities and involvement?

Dr. JACOBS. I would say they facilitate it, particularly on the data acquisition side. So there's been—we've had a very good experience in working with them and contracting for aircraft data. It's been a little tricky navigating the re distribution rights issue but by and large we're very happy with how things have gone, and I believe and they believe that it's improving their mission, improving their models and improving their forecasts.

Mr. WEBER. Okay. Well, I didn't mean to put you on the spot but I wanted to put you on the spot.

Dr. MacDonald, I'm going to come to you with the same question, and Dr. Jacobs, I want you to think about it. You said it was a little tricky. I'm going to give you a one minute warning here to facilitate some of that stuff. You'll get your chance to abuse the witness.

Dr. MacDonald, I'm going to come to you, same question. Do you think NOAA facilitates, hinders or resists commercial weather opportunities and involvement?

Mr. MACDONALD. I think in our case, in Spire, we have good hopes that we're going to have a great relationship with NOAA. I appreciate Neil's comment because they've dealt with this issue already, and he said it was tricky but they got through it, so I'm really hoping that in our case with fabulous satellite data we really have that opportunity to help the world.

Mr. WEBER. And Dr. Jacobs, back to you. Your one minute is up. You said it was tricky in them doing it. How so?

Dr. JACOBS. So traditionally, per the WMO's Resolution 40, most data that's produced by NOAA is redistributed freely to the other government international met centers. That impacts our business model because if we want to sell it to the European center, we can't sell it to the European center if NOAA buys it from us and gives it to the European center. There is a provision in the WMO Resolution 40 that allows for redistribution restrictions for commercially acquired data provided it's defined as non-essential. So we've asked that that be restricted for the purposes of sort of forcing the WMO members into a cost-sharing model. So if we actually prevent redistribution, then we get to charge NOAA less because we can actually sell it to the other government international met centers, thereby sort of forcing a cost-sharing model on all the government agencies worldwide.

Mr. WEBER. But I'm assuming you make up that income difference by selling it to the other agencies?

Dr. JACOBS. We're currently in contract discussions with both the European center and the U.K. met office for data acquisition. Every government met center has their own special needs. For example, some smaller countries don't even run a global model so they're only interested in the regional data around their domain.

Mr. WEBER. Okay. This really, I guess, is a question for the three on the right here. We'll start back with you, Dr. Jacobs. Do you see any bias from NOAA in certain weather predictions? In other words, I'm speaking specifically about climate change, global warming, sea-level rise. Are you seeing any bias whatsoever?

Dr. JACOBS. Most of the forecasting that Panasonic is involved in is in the zero- to 2-week range. Every numerical model has its own unique bias characteristics but that's more in the weather, not really so much in the climate.

Mr. WEBER. Fair enough.

Is it Busalacchi? Is that how you say it?

Dr. BUSALACCHI. Perfect.

Mr. WEBER. Okay.

Dr. BUSALACCHI. With respect to the science of weather and climate, absolutely no bias at all.

Mr. WEBER. That's good to hear.

Dr. BUSALACCHI. What I say, though, is with respect to model development for weather, the agency faces almost a catch-22. If they choose a model that's developed in-house, they will be criticized by the external community for a "not invented here" syndrome. If they choose a model from the community that's not invented within the agency, they're going to get criticized, well, why are you making this investment inside the agency when you can get it outside. So they're darned if they do and they're darned if they don't.

Mr. WEBER. All right. I'm going to move over to you, Dr. MacDonald.

Mr. MACDONALD. I do not see bias. I see scientists who argue about all aspects of it, and with reports like IPCC and others, I think it's well represented, and no, I don't see a bias.

Mr. WEBER. Okay. That's good to hear.

Mr. Chairman, I yield back.

Chairman BRIDENSTINE. The gentleman yields back.

Dr. Jacobs, just to follow up, if you—if your goal is to sell data to the Europeans or your goal is to sell data to NOAA, why did you build your own model?

Dr. JACOBS. Well, part of the reason for that was, we can't fully subsidize the cost of collecting the data so to run the data off the aircraft through SATCOM is quite expensive. So we offset that by generating products and services. The main reason why we actually run the models is to do quality control on the data because what we wanted to do is have the customers get the best value and impact of the data.

Chairman BRIDENSTINE. So it's to test the data? That's———

Dr. JACOBS. It's to test, and when we do provide the data, we provide a set of quality control flags along with the data. Those are derived from the data assimilation component in our model.

Chairman BRIDENSTINE. Okay.

I'd like to recognize the Ranking Member of the full Committee, Mrs. Johnson, for five minutes.

Mrs. JOHNSON OF TEXAS. Thank you very much, Mr. Chairman.

Dr. Busalacchi, I think what I'm hearing is that the NWS and the U.S. best work together or are at their best working together. Is that right?

Dr. BUSALACCHI. That's correct. Again, I think a unique strength of our approach, the U.S. approach to the Nation's weather enterprise, is when the government, the private sector and the research community are working together all towards a common purpose. That's correct.

Mrs. JOHNSON OF TEXAS. I have seen a great improvement in weather predictions, and I hope that'll continue to improve because I've also seen where it saved a lot of lives even though in many cases there might be property destroyed. Lives are being saved because of those projections and people have time to get out of the way.

We also talk a lot on this Committee about changes killing jobs, and I'm trying to figure out if it's privatized, what would happen to these seasoned employees that are government workers?

Dr. BUSALACCHI. So I'm sure there's great concern within the agency. I mean, I used to be—the two of us used to be civil servants and so they provide this core support that has allowed over the last 20 years my colleagues here in the private sector to build off that. If that core support is gone, we may have some near-term gains but in the mid to long term the enterprise may well collapse on itself because that core of the data and these foundational models just won't be there for the private sector to flourish.

Mrs. JOHNSON OF TEXAS. Thank you, Mr. Chairman. I yield back.

Chairman BRIDENSTINE. The gentlelady yields back.

I'd like to recognize the gentleman from Texas, Mr. Babin, for five minutes.

Mr. BABIN. Thank you, Mr. Chairman. I appreciate it. And thank you, witnesses, for being here.

I'd like to ask my first question of Mr. Myers of AccuWeather. Mr. Myers, who makes up the American weather industry, quote, unquote, and what steps could be taken to improve cooperative relationships between NOAA and these companies? If you could elaborate on that, I would appreciate it.

Mr. MYERS. Well, I think different people have different definitions of what constitutes the American weather industry. If you look at some of the groups like the Weather Coalition or the American Weather and Climate Industry Association, they're very welcoming of all members who touch upon any form of weather information and forecasts from the data collection itself all the way through the modeling and to the distributors of information. So I think the definition is relatively broad. Your second question was?

Mr. BABIN. What could we do to improve cooperative relationships between NOAA and these particular companies that you just mentioned?

Mr. MYERS. Well, this has been an ongoing effort at least that I've been involved in for 20-some years actively, and I think that it is generally improved. If you looked at a chart, it would be on the upswing. I think there needs to be further interaction at all levels of NOAA. I think that NOAA could benefit from better understanding exactly what the value is that the weather industry brings to the whole weather enterprise. We do get a lot of that recognition now in many of the management areas. A number of years ago when you talked about these things, it was looked upon as though we were competing somehow with what the government does but quite to the contrary, I have been here to testify and on other committees many times in support of funding for NOAA and the job that they do. I think that things like the EISG committee as part of the SAB for NOAA has over the last six or seven years it's been in existence has been very beneficial in interacting and

enhancing that communication, and I think activities like that need to continue and be strengthened.

Mr. BABIN. Okay. Thank you. And in your mind, what is the goal of weather forecasts in the future? How far out will we be able to accurately predict the weather, and are there specific goals for the next five, ten, fifteen years?

Mr. MYERS. Well, I know at AccuWeather, we're constantly pushing the envelope, and we sometimes get criticized for doing so. We launched a 90-day forecast, for example, that has day-by-day predictions that some have made a joke of, but the fact is that there's actual science behind it. I know when we first started introducing a 5-day forecast decades ago, people said the same thing: "You can't do it." I think that there is no end to what you can do. Our accuracy, for example, with tornado and hurricane forecasting is literally amazing. We have had plants evacuated 20 minutes before they've been totally destroyed by tornados and saved all the lives inside. The U.S. Congress in its report on Hurricane Katrina talked about how AccuWeather was in fact the only organization that had it right and far enough in advance.

So there are lots of things that can be done. I think that better understanding of what in fact the private sector does in forecasting is very important because we do specialize in a number of areas and activities, and even outside independent sources now that do ranking of forecasts have shown that the AccuWeather forecasts are actually statistically more valid than anybody's, and there are ways that that happens. It's not just magic.

Mr. BABIN. Absolutely. Thank you so much.

Mr. Chairman, I yield back the balance of my time.

Chairman BRIDENSTINE. The gentleman yields back.

I recognize the gentleman from Colorado, Mr. Perlmutter.

Mr. PERLMUTTER. Thank you. I was told I had to go very, very, very last since I'm not on the Committee, so I'm happy to go or I'm happy to wait my turn.

Chairman BRIDENSTINE. We'll let you go.

Mr. PERLMUTTER. Thank you, sir.

And to the panelist from Colorado, welcome. Dr. MacDonald, good to see you. Dr. Busalacchi, nice to have you. And gentlemen, I appreciate the testimony because one of the things I'm hearing generally is that there's an effort to work together to improve weather forecasting, predictions across the board, and as we've talked about in this Committee, for life, for property, for commerce, looking at those things, and a lot of the conversation that we've had when it comes to, you know, industry participating in weather forecasting is really just a matter of contract, you know, who's going to get this advantage, who's going to get that advantage, who gets the redistribution rights, what are the royalties, those kinds of things, and if you're actually having a conversation and a dialogue, which it sounds like you are, then you can work out those contractual matters, and I appreciate the efforts being taken by everybody in this respect.

And Dr. Busalacchi, congratulations on your appointment to head UCAR, and obviously that's a very important organization for Colorado at the National Climate and Atmospheric Research Center. So I appreciate the efforts to continue to work together because

I do think it's a three-legged stool as you're talking about. You've got academia, the private sector and government because the one thing we know is the private sector is interested in profits, and that's okay. That's the way it works. And if there isn't profits, then the question is, is that private company going to be altruistic and look out for the public good. Sometimes maybe yes but mostly no because they've got to talk to their shareholders and provide for their shareholders.

So having given that little speech, Dr. Busalacchi, some entities such as some of the companies represented today that the Weather Service should focus on its core forecasting functions and should not duplicate services that are already provided by the private sector. What's your opinion of that? Although I'm not sure I ever heard them say that.

Dr. BUSALACCHI. No, I didn't hear it either, and one of the issues is, you know, who's going to arbitrate. So again, the role of the government, as I said before, is protection of life, property, support of economic competitiveness, and homeland and national security, and to do that, the government needs to be in the cutting edge and have these foundational data sets where we are the best in the world and then also have these free and open models so that my colleagues here can build upon it but again that those models need to be the best of the best, and as my colleague Sandy mentioned, the best way of being the best of the best is this community approach, taking advantage of the strengths of the academic community and the strengths of the private sector so that these core foundational models are at the forefront and the world's best.

Mr. PERLMUTTER. Thank you. And I'm going to turn to you, Dr. MacDonald, in just a second, but I wanted to thank all three legs of the school: academia, government and private industry. We have some constituents who were missing during Cyclone Winston down in the Fiji area, which was a huge storm down there, and among the three, we were able to determine even though there was no communication that the path of the storm kind of bypassed them, and it brought a lot of comfort to the family members in my district. So NCAR and UCAR helped me, NOAA helped me, and Digital Globe and a number of other companies, so thank you.

So Dr. MacDonald, my question to you is, now that you moved from the NOAA world to Spire, how do you see the collaboration and the cooperation?

Mr. MACDONALD. Well, I think it's going to take time to, you know, learn how to get the kind of relationships that we need. What I see is that—I joined Spire basically because I see a fabulous capability that could become available, you know, very quick and that I don't think would in the normal course of our federal acquisition be available anywhere near as fast, so my hope is we work great together and we get better weather forecasts a lot sooner because of this situation.

Mr. PERLMUTTER. Thank you. I yield back.

Thank you, Mr. Chairman, for letting me go out of order.

Chairman BRIDENSTINE. The gentleman yields back.

A couple of important points I'd like to make, because there is a balancing act here between the public good and the private sector, and I think all of us on both sides of the aisle agree that we

absolutely must have a government backbone because it is for the lives and safety of our citizens but also for the property of Americans. So I agree with that completely.

I also believe that there's a commercial industry launching. Whether it's devices that are on aircraft or whether it's devices that are on satellites, at the end of the day they're going to be selling data to the commercial sector, and if by selling to NOAA, NOAA gives the data way for free, then they will never sell to NOAA and the public sector will miss out on critically valuable pieces of information that ultimately could save lives and property. So this is a balancing act that we're going to have to figure out why this Committee is so important.

I'd like to recognize Mr. Westerman for 2 minutes. We have to be on the Floor of the House technically at 10:35, so we're going to go to 2-minute questions, so get your most important ones ready, and we'll go from there.

So Mr. Westerman, you're recognized for 2 minutes.

Mr. WESTERMAN. Thank you, Mr. Chairman.

Mr. Myers, you reference in your testimony the widespread use of smart devices these days. With the ever-expanding ability of crowdsourcing as a tool such with the success of the traffic app Waze, do you see this being applied to weather reporting in any way?

Mr. MYERS. Yes, absolutely it will be. The collection of information through crowdsourcing, through vehicle sensors and a whole host of other things is an important area. It's one that we have worked in extensively. In fact, we had one of the first patents having to do with the collection and reporting of severe weather through mobile devices, which, interestingly, for the Committee, we license for free to the National Weather Service because they were using that capability, and we felt it was so important. You know, people talk about the private sector but if you look at the company mission for AccuWeather, it starts out to protect lives and property, not to make a profit, not that we don't want to make a profit but—and it's our mission statement. Yes, it is. In fact, if you look at ours and the Weather Service's next to each other, you have a very hard time distinguishing the difference.

I think that's true of most of the people that are in this field. They feel a strong obligation to the public to do these things, and constantly looking for ways to improve by using this kind of information.

Mr. WESTERMAN. And because we're limited in time, I'll just ask Mr. Block if he'd like to add to that.

Mr. BLOCK. Well, I certainly agree with a lot of the things that Barry is saying. In fact, we serve—my company serves over a thousand public emergency managers with our systems and our capabilities, and a lot of that information comes from NOAA, but it's disseminated—it's our systems that are actually the means of dissemination so for Schneider Electric, it's very important that we continue to work closely with NOAA and make sure that we're not in a competitive situation but in a cooperative one.

Mr. WESTERMAN. I yield back, Mr. Chairman.

Chairman BRIDENSTINE. The gentleman yields back.

The gentleman from Alabama, Mr. Palmer, is recognized for two minutes.

Mr. PALMER. Thank you, Mr. Chairman.

Mr. Jacobs, I read an article where it talked about Panasonic's weather forecasting model that's among the best and maybe even the very best in the world, and there were some questions raised about whether or not Panasonic would share that model with NOAA or other organizations. Could you comment on that, please?

Dr. JACOBS. Yes. Those—we do intend to share the information. What sort of form the information is shared in may depend on the licensing arrangement and redistribution rights obviously. Sharing the gridded data would be a lot different than sharing visual plots of model output, which can convey the same information, but the gridded data can actually be used for product generation, and if they redistributed the gridded data, it would negatively impact our business model. There are certain things that we can provide the Weather Service with to help improve their mission that wouldn't negatively impact our business model, and we would certainly do that.

Mr. PALMER. How would Panasonic share information, for instance, with NOAA, you know, to provide necessary information to protect lives and property?

Dr. JACOBS. Well, a good example of that would be the aircraft data. So we currently have a contract to sell NOAA a subset of our aircraft data, but in times in the past when there's been a national emergency, we typically define that as when the National Weather Service decides to do supplemental radiosonde launches at either 16 or 18 Z. When those alerts are issued, we will activate the full feed to pipe them the remainder of the data at no charge.

Mr. PALMER. Well, considering that Panasonic claims to have the world's best, and I hope you do, I think this Committee would join me in looking forward to seeing that model.

I yield back.

Chairman BRIDENSTINE. The gentleman yields back.

And I'd like to—for Mr. Myers, regarding giving the data away for free, from my assessment, I absolutely 100 percent am committed if the government is creating the data with taxpayer money, that is public data, and I fully support making sure that that data is available to the world as part of our WMO 40 agreements. It's the commercial data that is licensed that we have to be concerned about because if we don't do it right, then that commercial data will never be created, and if it's not created, then it can't be a public good for anybody.

I'm going to go to Mr. Rohrabacher here in just a few minutes. Ms. Bonamici had a quick question. Would you mind if I yielded to her for one minute?

Ms. Bonamici.

Ms. BONAMICI. Thank you, Mr. Chairman.

I just wanted, Dr. Busalacchi, if you could address what process is involved in validating the models and forecasts that are disseminated by the National Weather Service? Because if we're talking about or contemplating greater use of private data forecasts or models, should there be some similar validation or verification process before potential use in operational NWS forecasts?

Dr. BUSALACCHI. So anything in the public domain is fully vetted, it's transparent. When dealing with the private sector, we have to talk about validation, verification, transparency. Our particular company, are their getting the right results or good results for the right reason? Can it be replicated? Can it be tested? That's all part and parcel of the scientific method, but at the same time, sometimes that's in conflict with intellectual property. But in terms of the public good, it has to be transparent, it has to be traceable in the peer-reviewed literature, absolutely.

Ms. BONAMICI. Thank you, Mr. Chairman. I yield back.

Chairman BRIDENSTINE. The gentlelady yields back.

I now recognize Mr. Rohrabacher for two minutes.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman.

Just some fundamentals. How many weather satellites are there? When was the first weather satellite put into orbit?

Mr. BLOCK. I believe that the first weather satellite was launched in the early 1960s. It was the TIROS satellite.

Mr. ROHRABACHER. I remember—Mr. Chairman, I remember sitting through a hurricane back in the 1950s. We had almost no advance notice on it, and I'll just note that what we're talking about here saves not only lives, which are very important, probably thousands of lives, but also billions and billions of dollars. In that way, this is an industry that's paying for itself in so many ways, and the fact that the private sector is now deeply involved in this I think this is a very—an American story of success, and I want to thank the witnesses for enlightening us today as to details.

One last—I'm sorry—perhaps a little bit more controversial question is, are experiencing more severe weather incidences today than they did 100 years ago? Just a yes or no down the line if I could.

Mr. MYERS. Not being a scientist, I'm going to pass on that question.

Mr. ROHRABACHER. All right.

Mr. BLOCK. I think the answer is yes, there is more—there are more instances of severe weather, but it's largely a function of the population and the urbanized areas increasing in size so there's more people to observe them.

Dr. JACOBS. I would agree with that answer. I think that there's a lot more observations so it tends to show———

Mr. ROHRABACHER. So in other words, it's not more severe weather, it's just that we see more of it, especially now that we have so many satellites up there?

Dr. JACOBS. Well, we don't necessarily know for sure because the inverse of that would be, there were no observing systems or observers back then, so we don't know if it was happening or not.

Mr. ROHRABACHER. All right.

Dr. BUSALACCHI. So where we have long contiguous records, we do see an increase in extremes. In addition, we have an increase in population that's becoming more vulnerable to those extremes.

Mr. MACDONALD. I think Tony's answer captures my thoughts.

Mr. ROHRABACHER. Okay. Thank you very much, Mr. Chairman.

Chairman BRIDENSTINE. The gentleman yields back.

I'd like to thank the witnesses for their valuable testimony and the members for their questions.

The record will remain open for two weeks for additional comments and written questions from members.

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Neil Jacobs

Committee on Science, Space & Technology
"Private Sector Weather Forecasting: Assessing Products and Technologies"

Questions for the Record to:
Dr. Neil Jacobs, Chief Scientist, Panasonic Weather Solutions, Panasonic
Submitted by Ranking Member Eddie Bernice Johnson

During the question and answer portion of the hearing, you testified that "There is a provision in the WMO Resolution 40 that allows for redistribution restrictions for commercially acquired data provided it's defined as non-essential. So we've asked that that be restricted for the purposes of sort of forcing the WMO members into a cost-sharing model. So if we actually prevent redistribution, then we get to charge NOAA less because we can actually sell it to the other government international met centers, thereby sort of forcing a cost-sharing model on all the government agencies worldwide."

- Could you elaborate on how you envision such a cost-sharing model working in practice?
- Would you consider your data to be "non-essential"?

Panasonic

September 7, 2016

The Honorable Eddie Bernice Johnson
U.S. House of Representatives
Science, Space and Technology Committee
Washington, DC 20515

RE: QFR from Environment Subcommittee Hearing on June 8, 2016
Private Sector Weather Forecasting: Assessing Products and Technologies

Dear Representative Johnson:

On behalf of Panasonic Weather Solutions, a division of Panasonic Avionics Corporation, it is my pleasure to provide these answers to your questions.

Would you elaborate on how you envision such a cost-sharing model working in practice?

The World Meteorological Organization (WMO) has 191 members. Of these members, there are approximately eight key members (or organizations) that run global models (e.g., United States National Weather Service (NWS), European Centre for Medium-Range Weather Forecasting (ECMWF), Japan Meteorological Agency (JMA), etc.) that would be able to make use of the Panasonic TAMDAR[1] aircraft data.

If NOAA redistributes the Panasonic data to these other agencies, it would prevent Panasonic from being able to sell the same data to these agencies.

Panasonic is not opposed to NOAA redistributing the TAMDAR data to these other agencies; however, to make that arrangement a sustainable business model, Panasonic would need to charge NOAA approximately eight times more than they are currently paying.

Alternatively, NOAA can restrict the redistribution of data, which means the other key global meteorological agencies will have to purchase the data from Panasonic. Those agencies will be charged approximately one-eighth of the cost. This is essentially a "cost-sharing" business model. The arrangement does not have to be equal one-eighth parts, but can also be a based on a fraction of GDP or a similar metric.

Once the costs are recovered from the main WMO members, the data can be redistributed among the remaining smaller members at no additional cost. The benefits of this cost-sharing model to the international community are as follows:

1) NOAA can purchase much more TAMDAR data without increasing their budget
2) The cost to NOAA equates to an 87% discount
3) Other key WMO members realize that same discount by sharing the cost
4) Smaller WMO members benefit by receiving additional data that would normally be out of their budget

[1] Tropospheric Airborne Meteorological Data Reporting

RE: QFR from Environment Subcommittee Hearing on June 8, 2016
Private Sector Weather Forecasting: Assessing Products and Technologies

Would you consider your data to be "non-essential"?

At Panasonic, we consider TAMDAR data a critical component of Panasonic's forecasting system because the inclusion of these data provides additional forecast skill improvements exceeding 50%[2].

The WMO Annex I to Resolution 40 (Cg-XII) subpoint 3 states that "all available aircraft reports, e.g., data in AMDAR, AIREP codes, etc." are essential[3]; however, it also excludes commercial data with re-export restrictions from being defined as "essential" data.

Therefore, regardless of the criticality and benefit Panasonic TAMDAR data may provide, the re-export restrictions prohibit it from being listed as an "essential" data source according to the WMO.

However, in the spirit of the WMO's mission, Panasonic does provide various TAMDAR data, at no cost, to the research and education community. For example, NOAA's Earth System Research Laboratory (ESRL) has a no-cost TAMDAR data feed, as does the National Center for Atmospheric Research (NCAR), University of Washington (UW), North Carolina State University (NCSU), University of Maryland (UMD), and University of Oklahoma (OU). These license agreements simply require that the data is used only for educational and research purposes, and the data cannot be redistributed.

I would be happy to provide you or the committee staff with additional information if needed.

Sincerely,

Neil A. Jacobs, Ph.D.
Chief Atmospheric Scientist
Panasonic Weather Solutions

[2] https://www.hindawi.com/journals/amete/2015/427616/
http://journals.ametsoc.org/doi/abs/10.1175/2009WAF2222321.1
[3] http://www.wmo.int/pages/prog/www/ois/Operational_Information/Publications/Congress/Cg_XII/annex1_en.html

Responses by Dr. Antonio Busalacchi

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Subcommittee on Environment

Hearing Questions for the Record
The Honorable Suzanne Bonamici (D-OR)

Private Sector Weather Forecasting: Assessing Products and Technologies

Questions for Dr. Antonio Busalacchi

1. What would be the implications of private companies assuming responsibility for producing forecasts?
   - If NWS did not develop forecasts, would Federal and State governments have to purchase their weather forecasts exclusively from private companies?
   - If the private sector, rather than NWS, disseminates weather information, is that a sustainable model? If not, why not?
   - What other issues might arise if NWS were to cease producing weather forecast?

2. During the question and answer portion of the hearing, Dr. Jacobs testified that "There is a provision in the WMO Resolution 40 that allows for redistribution restrictions for commercially acquired data provided it's defined as non-essential. So we've asked that that be restricted for the purposes of sort of forcing the WMO members into a cost-sharing model. So if we actually prevent redistribution, then we get to charge NOAA less because we can actually sell it to the other government international met centers, thereby sort of forcing a cost-sharing model on all the government agencies worldwide."
   - What would be the implications of such a cost-sharing model?
   - How would such a cost-sharing scenario work in practice? What issues do you see with it?
   - What is meant by Dr. Jacobs's reference to commercially acquired data that is defined as non-essential?

Answers to questions for the record from testimony by Antonio Busalacchi before House Committee on Science, Space and Technology

Responses to questions submitted by Congresswoman Bonamici:

1) What would be the implications of private companies assuming responsibility for forecasts?
    a. If NWS did not develop forecasts, would Federal and State governments have to purchase their weather forecasts exclusively from private companies?
    b. If the private sector, rather than NWS, disseminates weather information, is that a sustainable model? If not, why not?
    c. What other issues might arise if NWS were to cease producing weather forecasts?

There would be multiple challenges to American citizens, private companies, and national security if private companies assumed all responsibility for producing forecasts. Most importantly, quality of forecasts would degrade in the long-run as the federal forecasting infrastructure that supports advances in forecasting from academic research to operations would disappear. In addition, many forecasting products critical to national needs would no longer be provided, as the private sector does not cover the breadth and depth of forecasting activities that NOAA currently supports. Producing forecasts for the public good is not the same as producing forecasts for profit.

Citizens, companies, and national security personnel receive reliable forecasts from the National Weather Service (NWS). If private companies were to assume responsibilities for forecasts, discrepancy in forecasts between private companies could cause confusion, particularly during the anomalous high impact weather event. Under this scenario the public would be subjected to a *caveat emptor* situation. At present, the Federal Government is viewed as a trusted source for weather information, that would be lost if multiple companies assumed the responsibility of the forecasts and no provision of forecasts by the government. In such an event, the public's ability to take proper precautions may be compromised by this approach. The protection of life and property are inherently governmental activities, and the government would not be able to perform these duties effectively with differing private forecasting products disseminated to the public.

A business model for private companies' sole provision of weather forecasting does not yet exist. Federal and State governments would likely need to purchase private forecasting services for their own purposes (e.g. NASA's need for reliable weather forecasting for launch scheduling) or for the protection of life and property (e.g. issuing watches and warnings). To evaluate and select from among the competing forecasting services, the Federal government would require internal expertise in weather forecasting. This expertise would be lost if the Federal government

was not actually making forecasts. Similarly, these personnel, as they are now, would need to be continuously educated in new and developing forecasting technologies and techniques, and there would need to be many forecasting personnel to evaluate the litany of different weather forecasting products the government requires. Such a skill set goes far beyond that of a procurement officer that would be involved in deciding what private sector forecast to purchase. Additionally, these personnel would need extensive experience in active forecasting and in developing forecasting models to hone their expertise. As such, even with the assumption of weather forecasting responsibilities by the private sector, the government would still need to maintain a forecasting apparatus or "backbone" that would require funding.

How the private sector would interact with the general public in the provision of forecasting services is also unclear. If the private sector forecasting products would be purchased by the government and, in turn, the government would then distribute forecasts, then it would simply be a government contracting arrangement. Indeed, government contracting arrangements already exist in the synthesis of National Weather Service forecasts. How this arrangement would differ is unclear. If the Federal government could not distribute the forecasts it purchased to second and third party users of the information without the consent of the private sector, and instead the general public would then need to purchase forecasting services, it would create a Gordian knot for the end user. It is also unclear how such provision would occur and how to inform citizens, state and local governments, private companies, and national security entities what forecasting services they require for their specific weather requirements. Even if such business models and models for provision could be constructed, the transition to them would be very difficult and potentially dangerous.

Furthermore, under this scenario, the quality of the observations, effectiveness of research, and the overall skill of weather forecasts will likely suffer. A strength of free and open access to weather forecasts and all the attendant infrastructure is the feedback that ensues to the research and observational communities. The actual process of making day-to-day forecasts and the free, open, continuous validation and verification of those forecasts enable the research community to analyze why a forecast succeeded and why it failed. This leads to a process of continuous improvement to the forecast skill. Similarly, such day-to-day open confrontation of the model with observations allows ongoing assessment of the observing system and where new observations are needed to advance forecast skill. The confidentiality of the private sector business model is anathema to this community approach to advancing forecast skill. Moreover, because NOAA's forecasting operations are in the public domain, scientists can easily perform research using NOAA forecasting products and tools. Additionally, scientists can incorporate the forecasting products and tools into their instructional materials, providing immense benefits to training the next generation of weather professionals for both the government and private

sector. Because private companies' forecasting methodologies and apparatus are proprietary, these materials would not be available for research and pedagogy.

Maintaining a strong governmental weather forecasting capability is essential to national security. To conduct missions around the world and in space, the Federal government requires an array of weather forecasting products. In the event of war, acts of terrorism, and other threats to homeland security, specialized weather products are needed to support our defense leadership, the warfighter, as well as first responder, and these products need to be developed rapidly. These duties are inherently governmental, as we cannot afford the risks associated with the outsourcing of national security activities.

Finally, indemnification is an important issue. Will the public be able to litigate against private companies for bad forecasts? Current federal policy allows for forecasting error and mistakes. Will this approach open the door to litigation over forecast errors and what constitutes error? Opening this Pandora's box will not improve forecasts and could potentially waste important resources in an area that does nothing to help our nation.

2) During the question and answer portion of the hearing, Dr. Jacobs testified that "There is a provision in the WMO Resolution 40 that allows for redistribution restrictions for commercially acquired data provided it is defined as non-essential. So, we have asked that that be restricted for the purposes of sort of forcing the WMO members into a cost-sharing model. So if we actually prevent redistribution, then we get to charge NOAA much less because we can actually sell it to the other government international met centers thereby sort of forcing a cost-sharing model on all the government agencies worldwide."
    a. What would be the implications of such a cost-sharing model?
    b. How would such a cost-sharing scenario work in practice? What issues do you see with it?
    c. What is meant by Dr. Jacobs's reference to commercially acquired data that is defined as non-essential?

This argument is not sound and if enacted jeopardizes our relationships with foreign governments, on which we depend for the provision of free real-time essential data. It would appear that parts of the private sector want commercially acquired data deemed "non-essential" solely for the purposes of preventing NOAA et al. from sharing such data with other governments. However, data should be deemed essential or non-essential based on whether the data is actually essential or non-essential, not whether it satisfies a private company's business model. Traditionally, the WMO and NOAA have understood that essential data are any global data that makes a significant impact on global forecasts; data specific to exclusive regions or data that does not make an impact on global forecasting models are

non-essential. Any change to this reading should be done in conjunction with our international partners as we would not want them to discontinue the provision of global data to us. Any attempt by the U.S. to unilaterally proceed along these lines will have little chance to succeed within the international arena. As I stated in my written testimony: "I believe the future weather enterprise will be much more integrated today because countries cannot afford to build the tools such as satellites and models by themselves and they realize that be integrating their systems with other countries they will get a bigger return on their investments. Observations have led the way. In 2003, the United States led an effort called the Global Earth Observing System of Systems (GEOSS) and it is a prime example of international coordination that leads to integration and alignment. The developed countries who are signatories to GEOSS bring large observing systems to the table and the developing nations bring areas that have not had access to observations and the associated products and services that result."

The proposition of a "cost-sharing" model for the provision of commercially acquired data is not consistent with the past practices of the private sector. Presumably, a cost-sharing model would be exactly that – a company's costs in creating a service or product would be revealed and customers would then divvy up their shares of the payment. However, private companies do not make public the costs associated with developing a product or service, so customers would simply have to trust that a private company's prices are reflective of "cost-sharing" – this would be a highly unusual business model.

Private companies charge customers for their products not based on the cost of the product, but based on the customer's willingness to pay for the product (with consideration given to all alternatives). A private sector CEO is interested in maximizing her/his company's profits (indeed, that is her/his duty to shareholders) and prefers that customers not share the product not because of a concern that a customer would be charged more for the product if it then shared it with the world, but because s/he would prefer to have as many customers as possible, accruing as much revenue as possible. Thus, the notion is antithetical to the way business works; hence the concept of a "cost-sharing" mode is unfounded

If a commercially acquired data provider were interested in establishing a cost-sharing model, s/he could do so without a contorted reading of WMO Resolution 40: s/he could convene representatives from several meteorological services and offer to make a single sale to the whole group for a single price, with each met service chipping in according to the importance and quality of the information, their need and ability to pay. Private companies regularly orchestrate the provision of payment for a single product from multiple government entities; such a model is possible for commercially acquired weather data. This is indeed a strength of the international approach to weather observations and forecasting.

Committee on Science, Space & Technology

"Private Sector Weather Forecasting: Assessing Products and Technologies"

Questions for the Record to:
Dr. Antonio Busalacchi, Director, Earth System Interdisciplinary Center, University of Maryland
Submitted by Ranking Member Eddie Bernice Johnson

1. During the hearing the "Panasonic model" was discussed, and we also heard references to Panasonic's use of the National Weather Service (NWS) Global Forecast System (GFS) numerical model.
   - Based on your understanding, how does the Panasonic model differ from the GFS?
   - Given what Panasonic has made public about the performance of their model, is there enough information available at this point to verify the accuracy of the claims made about the models performance? If not, what additional information would you need to make that determination?

2. During his testimony, Dr. Jacobs referred to Panasonic using a global model, and then using their boundary conditions to force a high resolution model.
   - Can you explain what Panasonic is doing to reach a high resolution model?
   - Can you comment on the present approach used by the scientific community to predict on both global and regional scales?

Responses to questions submitted by Ranking Member Johnson:

1) During the hearing the "Panasonic model" was discussed, and we also heard references to Panasonic's use of the National Weather Service Global Forecast System (GFS) numerical model.
    a. Based on your understanding, how does the Panasonic model differ from the GFS?
    b. Given what Panasonic has made public about the performance of their model, is there enough information available at this point to verify the accuracy of the claims made about the models performance? If not, what additional information would you need to make that determination?

While limited results of the model modifications made by Panasonic show some initial success, it is important to realize that Panasonic's "model" has as its core the GFS and some elements of NCAR's Weather Research Forecast model to assimilate their collected TAMDAR aircraft data. The resulted "model" is likely largely similar to GFS - and to draw a distinction between the two would suggest that the Panasonic model stands on its own, which it probably does not (we do not know for sure, since the model is proprietary and has not been vetted in the government or academic communities, but colleagues that have worked with it substantiate the above).

More importantly, Panasonic's claims that its operational model is better than GFS and ECMWF has not been validated or verified; this claim cannot be made until the model is held to the same verification standards as Federal government models. Panasonic's proof consisted of nothing more than an arbitrary 500 correlation chart for a random two week period where Panasonic's GFS model scored better than the other operational models – this is hardly scientific validation and verification.

If Panasonic's model is truly independent from GFS, it would need to undergo an independent rigorous year-long testing regime constructed by leading academics and operational specialists applying best practices to assess the validity of the forecasting technique and its accuracy compared to government operational models to consider replacement. If its model is a tailored GFS, the new data incorporated and the resulting data assimilation techniques would need to be evaluated in a simulated experiment that would need to be performed at a research university or comparable research environment, where results and findings could be vetted and reevaluated by the academic community.

2) During his testimony, Dr. Jacobs referred to Panasonic using a global model, and then using their boundary conditions to force a higher resolution model.
    a. Can you explain what Panasonic is doing to reach a high resolution model?

b. Can you comment on the present approach used by the scientific community to predict on both global and regional scales?

Because Panasonic's global model is not available for academic review (as discussed in the previous question), those of us outside the company cannot be certain as to what their techniques are. They are likely using some form of WRF, a research model, nested within GFS.

The present approach used by the forecasting communities, be it public or private is to predict on both global and regional scales by using a higher resolution model like WRF with specified data at the boundaries. However, the research community is now moving in the direction of constructing and operating models that provide the capability to perform seamless multi-scale numerical weather prediction. For example, NCAR's Model for Prediction Across Scales (MPAS) uses uniform and variable-resolution unstructured horizontal meshes predicting large scale and small scale weather phenomena within the same model. This breakthrough will be exciting for the research and operational community because the model does not suffer from the problems inherent in traditional grid nesting where abrupt, discontinuous mesh transitions result in strong grid errors at the nest boundaries.

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