Opening Address to the Weather Channel Forum:
Policy Issues in Hurricane Preparedness and Response

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Topic: What policy changes are needed to produce weather services, media communications, and emergency management decisions that will optimize hurricane preparedness and response?

✍✍ Thank you, Ron. It's good to be here to open the Weather Channel Forum. I would like to thank Decker Anstrom for inviting me to speak. And I also want to acknowledge the valuable role of the American Meteorological Society in sponsoring this workshop.

✍✍ Let me start off on a positive note. I believe that this community, the hurricane community—composed of forecasters, the media, and emergency managers—is doing a very good job. Across federal, state, and local agencies, we manage to coordinate closely in times of danger. When I think about the impacts on society of hurricanes, I am grateful to know that we have top flight professionals working on these issues.

✍✍ As is the case in any discipline, things can always be improved. And that's why I am happy for this chance for the experts to get together and draw up some recommendations.

✍✍ Ron, Jeff, and Decker have already mentioned last year's hurricanes and how ferocious they were.

✍✍ As I was preparing for this talk, I began considering the hurricanes of the past. And naturally, this being the 100 year anniversary of the Galveston hurricane, that came to mind first. I began to think about the comparisons that can be made between the Galveston storm and Hurricanes Andrew, Mitch, and Floyd.

✍✍ In Galveston, in 1900, they certainly did not have any warning for the storm, and it showed: 8,000 dead and the equivalent of $30 billion (1998 dollars) worth of damage. We don't know that much about the Galveston storm, but I can make two points from Isaac Cline:

1. There was no warning. "The hurricane which visited Galveston Island on Saturday, September 8, 1900, is no doubt one of the most important meteorological events in the world's history…The usual premonitory signs which herald the approach of hurricanes were not present in this case. The brick-dust sky was not in evidence to the smallest degree…"

2. The first time observers see a hurricane, they don't understand the power. This is from Mr. Cline's autobiography: This being my first experience in a tropical cyclone I did not foresee the magnitude of the damage which it would do. Instead of washing away three blocks near the beach as I had warned early in the morning, an area more than six blocks wide was completely washed away, and some 6,000 persons lost their lives." We may be facing this problem more and more in the coming decade.

- Even more destructive than the Galveston storm was Hurricane Andrew, the third most intense U.S. land-falling hurricane this century, and the strongest since Hurricane Camille in 1969. Andrew was a Category 4 storm, and brought with it $37 billion worth of damage, and 38 lives lost. Obviously, this community saved many lives by warning people to evacuate. So with Andrew, we have a case of very high property damage, but relatively few lives lost given the magnitude of the storm.

- In fact, a more telling comparison is the Galveston storm and Hurricane Mitch, where we lost approximately 11,000 lives. Mitch, as you know, will go down in history as one of the strongest Atlantic hurricanes ever, lasting a total of 33 hours at Category 5 strength. And it was the deadliest hurricane of the past two centuries. Honduras bore the brunt of the storm, losing 6,500 persons with huge numbers missing. Up to 1.5 million people were displaced and left homeless in that country. There were shortages of food, medicine, and water. Hunger and near-starvation were widespread in many villages. Malaria, dengue, and cholera appeared, and epidemics were feared; fever and respiratory illnesses were widespread. The infrastructure of Honduras was devastated. Whole villages washed away, and an estimated 70 - 80 percent of the transportation infrastructure was destroyed. At least 70 percent of crops were destroyed, including 80 percent of the banana crop. Crop losses alone were estimated at $900 million. Total damage was estimated at $4 billion, and was so severe, it was estimated that it could take 15 years to 20 years or more to rebuild.

- Jack Kelly and Bill Proenza of the Weather Service have since traveled to Latin America and engaged our colleagues on how we can improve our collaboration.

- Finally, I can mention Hurricane Floyd: of 56 deaths, 50 were due to drowning. Other hurricanes have dropped lots of water. This is from *Isaac's Storm*: "In 1979 a tropical storm named Claudette blew off the Gulf of Mexico near Galveston and deluged the town of Alvin, Texas, with forty-two inches of rain in twenty-four hours, still the U.S. record for sheer intensity. A Philippine typhoon holds the world's record, dropping 73.62 inches in twenty-four hours. Total accumulations have been higher, however. Ninety-six and a half inches of rain once fell on Silver Hill, Jamaica, over four days. That's eight feet. In 1899 a hurricane dropped an estimated 2.6 billion tons of water on Puerto Rico. Hurricane Camille, which came ashore on the Gulf Coast in August 1969, was still flush with water two days later when it reached Virginia. With no advance warning from the Weather Bureau, it jettisoned thirty inches of rain in six hours. Hillsides turned to mud, then to an earthen slurry that flowed at highway speeds. In Virginia alone, 109 people lost their lives. Camille's rain fell with such ferocity it was said to have filled the overhead nostrils of birds and drowned them from the trees."

- Today and tomorrow, you will be considering what policy changes might be needed in the way we provide our weather services, communicate through the media, and manage our emergencies.

Since I manage a weather agency, let me briefly review the various elements of hurricane forecasting from NOAA's perspective.

✍✍ NOAA's role in hurricane forecasting depends on observations by aircraft and satellites, modeling to determine track and intensity, research, computing and people power, and dissemination of information.

Aircraft

✍✍ It was back in July 1943, that we entered the world of Hurricane Reconnaissance with another Hurricane that was bearing down on the Texas coastline. To satisfy his personal curiosity, Col. Joseph B. Duckworth, decided to make an experimental flight into a hurricane in a single-engine AT-6 Texas Trainer. I understand he made two flights into this hurricane. The first person to go with him was a navigator. The second time, the only other person that he could get to go with him was…a meteorologist. Why am I not surprised?

✍✍ Today, NOAA has a Gulfstream IV, a high-altitude jet aircraft whose primary mission is for operations to improve hurricane track and intensity forecasts. This aircraft is providing critical high-altitude data, which we've never had before, to fully define the steering currents of a storm. Preliminary studies are showing that improvements to our numerical track forecasts could be expected on the order of 20-25%.

✍✍ We are also considering an upgrade in the G-IV instrumentation to make high level penetrations with this aircraft. A new suite of instruments from high altitude would provide critical hurricane core information to provide our forecasters with a three dimensional picture of the storm from the top region to the surface, essentially telling us how big the hurricane is, how strong it is, and what kind of rainfall we can expect as the hurricane makes landfall.

✍✍ This platform will give you Emergency Management folks a map of the surface wind field telling you exactly how far the tropical storm force and hurricane force winds extend out from the center as the basis for critical evacuation information. This information will be also be transmitted instantaneously to NCEP for the initialization of our next generation hurricane models.

✍✍ This is new century technology that we expect to make inroads in improving not only our track forecasts, but also our intensity forecasts.

✍✍ Over these past thirty years, although many aircraft have flown into hurricanes, we have a lot to thank for the improvement of our understanding of hurricanes by the dedication and research of everyone associated with NOAA's P3s. These are the aircraft used in research by the many dedicated scientists at the Hurricane Research Division of AOML and maintained all of these years by the Aircraft Operations Center of NOAA who have brought much insight and understanding to the hurricane problem. Recently, one of our two P3s was damaged while on the tarmac in Galveston. Extremely strong winds loosened five surrounding aircraft, one of which struck the P3. The strong winds also damaged the plane's control surfaces. We expect that this P3 will be up and running by early September.

Satellites

- Satellite technology has aided us greatly in observing hurricanes. Better early warnings have softened the blow of flooding through better emergency planning.

- We are now acquiring very high-density wind data and have begun to assimilate these winds in our models. By utilizing the very rapid refresh rate of the future GOES, combined with improved resolution and availability of more channels and frequencies of information, we will have advanced cloud pattern recognition methods for intensity estimates, which could be automatically calculated using imagery available every five minutes.

- Our satellite-based atmospheric temperature and moisture instrument will contain 10-100 times more channels than the current sounder, allowing us to provide more precise water vapor detection, vastly improved vertical moisture resolution, SST measurements, and therefore more accurate and detailed descriptions of how the storm structure is evolving. This in turn will lead to better data assimilation in numerical hurricane forecasting models.

- In addition, other promising technologies such as LIDAR will also give us more accurate and detailed vertical profiles of wind, critical to forecasting storm motion, and SAR (Synthetic Aperture Radar), which has the potential to provide accurate surface wind estimates.

Modeling

- We will see a substantial impact of coupling the ocean with the atmosphere on forecasting hurricane intensity. This is the result of work being done by NOAA's GFDL lab in collaboration with the University of Rhode Island in which the explicit modeling of the air-sea interaction improves the GFDL intensity forecast by significant amounts. For the 72 hour forecast, the new coupled model reduces errors from 27 to 18 hectopascals. This model will run in a "semi-operational" state this coming hurricane season.

- Better observations and modeling have helped us decrease track errors over the Atlantic so that the 24 hour track error in the late 60's and early 70's was about 120 nautical miles, and now it is about 80 nm. The biggest improvement has been in the longer time scales. For example, we have reduced our 72 hour track error by 50% from over 400 nm to just over 200 nm. We would like to see similar improvements in intensity forecasts.

New Supercomputer

- Having just come through the National Weather Service Modernization, I think the horizon looks bright. We have a plan for our next generation satellites, and our 88D's (or Doppler Radar to you nonmeteorologists) are in place across the nation and along our at risk hurricane coastline. In addition, we have completed the installation of AWIPS in all of our forecast offices, and we have invested in training programs for our people.

- But will we have adequate computing power for the future?

- NOAA has invested in the latest high performance computing power to advance our data assimilation and hurricane prediction model outputs, and to provide a continuous upgrade to our hurricane forecasting capabilities.

- NOAA's new super-computer is the IBM-SP. It has 786 microprocessors that perform 25 to 30 billion sustained calculations per second. This is about FIVE times faster than the Cray that it replaced. In September, we will augment this to 2,048 processors. It will then reach 140 billion calculations per second, 28 times as fast as the Cray it replaced.

- This is the kind of computer power needed to run our next generation hurricane prediction model at 5km resolution with 50 levels in the vertical.

- The IBM is allowing us to start running very advanced data assimilation techniques to optimize the use of all the data that is available. As I mentioned earlier, this includes remote sensing data, which will increase in many orders of magnitude with the number of channels over the next decade, all the new critical aircraft data, and the use of the level-IIb data from our 88-D Radars.

Interagency Coordination

- NOAA is charged with the overall responsibility to implement a responsive, effective national tropical cyclone warning service. Many local, state, and Federal preparedness actions are taken to minimize loss of life and destruction of property. The joint participation by the Department of Defense (DOD) and the Department of Transportation (DOT) with the DOC brings to bear those limited and expensive Federal resources considered essential for storm detection and accurate forecasting. This cooperative effort has proven to be a cost-effective, highly responsive endeavor to meet national requirements for tropical cyclone warning information.

- NOAA provides various forecast and advisory services for hurricanes to DOD, provides facilities and the means to disseminate meteorological data to a DOD liaison based at the TPC/NHC, and provides basic meteorological data to DOD for the Atlantic, Eastern Pacific, and Central Pacific oceans. DOD provides NOAA with special satellite and aircraft-based observations of tropical cyclones upon request, in addition to meteorological data west of 180 degrees. The Department of Transportation provides flight control assistance to NOAA and DOD, support to the National Data Buoy Center, and surface observations from coastal facilities.

USWRP/Academy Recommendations

- The USWRP is a multi-agency initiative with NOAA taking the lead in improving the hurricane forecast and warning program. This program has been focusing on improving our projections of hurricane landfall and our quantitative precipitation measures. An increase in hurricane landfall forecasting skill is estimated to save $1 million per mile of coastline that is not evacuated.

- The recent Academy report, *The Atmospheric Sciences Entering the Twentieth Century*, provides some key recommendations regarding weather forecasting research and hurricanes:

1. Fundamental improvements in forecasting in the two-to-seven day range have enormous potential economic benefits but require far better collection and utilization of data over the oceans and other data-sparse areas. *We strongly encourage the support of research seeking to determine optimal combinations of satellite and ground-based remote sensing, and aircraft, balloon, and surface observations, as well as the support of key technological developments such as satellite-borne active sensing techniques, near-field remote sensing of atmospheric water vapor, and observations from commercial and pilotless aircraft.* Such research should include comprehensive, well-posed observing system simulation experiments (OSSEs) and data denial experiments. Cost-benefit analysis should play a key role in the definition of "optimal" as it is used above, and *the cost to the nation as a whole, rather than the cost to individual agencies, should be the criterion.*

2. Recent research strongly suggests that adjoint techniques or breeding methods can be used to target specific regions of the atmosphere for observational scrutiny during the subsequent data assimilation cycle, resulting in greatly reduced forecast error. We advocate enhanced research on adaptive observations and their potential for substantial reduction in forecast error.

7. The worst natural catastrophes in U.S. history were caused by tropical cyclones. Although research on the dynamics of tropical cyclone genesis, intensity and structure change, and motion is ongoing, it has received little emphasis in recent national programs or in the modernization of the National Weather Service. Little is known about the dynamics of landfallen tropical cyclones, and this has limited our ability to forecast related flooding. Detection of hurricanes has been greatly facilitated by satellite-based observations, but much of the current state of understanding as well as the quantitative prediction of storm motion and structure and intensity change has relied on in situ measurements. *We strongly recommend the support of research on the physics of tropical cyclone motion and intensity change, and of research seeking to delineate optimal combinations of measurement systems in aid of hurricane forecasting.*

8. Tropical cyclones and some classes of extratropical marine cyclones are sensitive to local sea surface temperature and are known to influence ocean temperature through wind induced stirring and upwelling. Modeling studies show that this feedback has an important effect on hurricane intensity, but observations of this interaction are lacking. *We strongly encourage enhanced observations of the upper ocean during the passage of tropical and some extratropical cyclones.*

- NOAA is now investing resources into examining the very latest techniques on adaptive observing strategies, including what combination of observations are best suited to improve forecasts and where should we take them to maximize the impact on our model forecasts. Necessarily, many of our resources go to research for continued model development and refinement of model physics.

- But all of our new technology means little if we can't get out the word to our customers.

Dissemination of Information

- Getting information out to the public is vital. NOAA and our partners, including local, state and federal emergency managers, have made inroads in this area. You have all done a tremendous job in educating people and getting them away from the coast preceding a landfall.

- I understand that since Camille there have been only 6 storm surge related deaths. But now, more lives are being lost from inland flooding. We must continue this educational process and help people to understand that hurricanes are not just a coastal event, but an inland-flooding event as well. Darrell Waltrip of the NASCAR circuit recently recorded a Public Service Announcement publicizing the dangers of driving through flooded intersections, and we anticipate that this PSA will receive airtime across the country.

- Some good news is that the number of users of NOAA Weather Radio continues to increase. We can also look toward the future and see that soon we will be able to deliver our warnings directly to people's cell phones and personal digital assistants.

- One of our major challenges continues to be communicating uncertainty, and I think we are getting better at this, but still have a ways to go.

Role of National Legislation

- In terms of policy considerations, one option this community might decide to pursue is federal legislation. The legislation might attract attention to hurricanes and response issues, and would be timed well with the change in phase of the decadal cycle. Earlier this year, interested parties gathered at Florida International University to discuss a proposed "National Hurricane Hazard Reduction Act." The Act's purpose would be to reduce the risks of life and property through the establishment and maintenance of a hurricane hazards reduction program. This program would develop better construction methods for buildings in hurricane prone areas, implement a system for predicting hurricane damage, develop policies that coordinate information about hurricane risk with land-use policy decisions and building activity, provide for better emergency planning and public education, fund research on the mitigation of hurricane hazards and consequences of hurricane impact prediction, assure the availability of hurricane insurance, and develop better techniques for forecasting hurricane track and intensity, surface winds, rainfall, and storm surge, and human and economic impacts.

- Let me conclude with a few questions you may want to consider over the next two days:

    1. What is needed to improve the accuracy of hurricane forecasts?
    2. What are the priorities for improving the forecasts?
    3. What policy changes are needed to make improvements available as soon as possible?
    4. What do emergency managers want from the forecasting community?

- I look forward to reading your recommendations in the conference report! Thank you very much for coming today.